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FINAL REPORT

Development of Computer-Generated Phenograms to Forecast Regional Conditions Hazardous to Low-Flying Aircraft

by

William E. Southern
Department of Biological Sciences
Northern Illinois University
DeKalb, Illinois 60115

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

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Collisions or strikes between birds and aircraft that occur annually across the United States result in damages amounting to millions of dollars and considerable risk to crew members. Gulls are involved in more strikes than any other group of avian species. USAF aircraft are vulnerable to birdstrikes during take-off, while landing, and during low-altitude missions. This report describes monthly patterns of gull distribution _

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across the United States and provides a statistical model for predicting the probability of one or more birdstrikes occurring. The accuracy of such predictions is dependent upon the input data for the model being as complete as possible. In addition, the data should be for the specific geographical area for which the prediction is desired. The following types of data are needed: (1) an estimate of the number of birds present in the area; (2) the number of missions flown in the area; and, (3) the number of strikes previously recorded in the area. With this information at hand, it is possible to determine how a change either in the number of missions flown or in the concentration of birds present will affect the probability of a birdstrike occurring.

The data available at this time on USAF mission patterns and previous strike locations were inadequate for the development of strike prediction tables for various parts of the United States. Data available for Langley AFB were used to show how the system can be applied. The procedure is statistically sound and appears applicable to the problem at hand; however, the mission-related data must be at least as detailed as the gull data before field testing is possible.

If predictions are desired for precise flight paths, more precise bird data will be required. The types of data currently available for gulls are evaluated and summarized in this report by 6° geographic Zones for the entire United States (except Alaska and Hawaii). In most instances, more detailed analysis of the gull data is provided than needed at this time for use in the model. The detailed information may prove useful as other sources of input data for the model become more refined.

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I. INTRODUCTION

Synopsis of the Bird Hazard Problem

Collisions between birds and aircraft have occurred throughout much of the history of aviation. The frequency of such events, as well as the seriousness of the encounters, has increased with the advent of high-speed aircraft equipped with turbine engines. This type of engine is more easily damaged in bird collisions and the amount of damage resulting from a birdstrike increases greatly as speed increases. High speed aircraft are particularly vulnerable to birdstrikes during take-off, landing, and low altitude missions. Although birds may strike almost any portion of an aircraft, they frequently are ingested into the turbine engines which form a large part of the frontal area of an aircraft. This poses a particularly important problem since loss of power during take-off can be devastating. In large aircraft, if more than one engine ingests birds, the problem is intensified because of a greater likelihood of operator error under stress (Ref. 1). Serious damage to aircraft and loss of life have occurred in both military and civilian aviation as a consequence of birdstrikes.

During the ten-year period 1967-1976, the United States Air Force (Ref. 2, 3, 4) annually reported between 322 and 466 birdstrikes (mean = 372.4). These figures (Table 1) include only those collisions between birds and aircraft that were severe enough to necessitate repairs to the aircraft invovled. More recent strike data (Ref. 5) supplied by the USAF indicated that 1142 strikes were reported between 1974 and 1977. If all birdstrikes were recorded, regardless of whether or not damage was caused to the aircraft, the total number of strikes would probably be three or four times higher. The annual monetary losses attributable to bird strikes amount to millions of dollars and the risk to pilots and crew members is substantial. As a result, attempts are being made in the United States and other countries to develop and implement procedures that will reduce frequency of bird-aircraft collisions.

Generally speaking, birdstrikes are infrequent, on the order of six to eight per 10,000 movements of passenger aircraft and somewhat more frequent in certain military operations (Ref. 1). The overall birdstrike rate for all U.S. Air Force aircraft during 1974 was one strike per 8036 flying hours while the rate for the F-111 tactical fighter bomber that flies low altitude missions was one strike per 2098 flying hours (Ref 9). In 1971, 39% of the 383 USAF strikes occurred in the immediate vicinity of the airfield (Ref. 4). Strikes have occurred at a wide range of altitudes but many (17.2% during 1974-1977) were reported at USAF Bases during take-off and landing. A large proportion (60.2%, 1974-1977) of the remainder occurred at altitudes below 1500 feet (Tables 2 & 3). Although most turbine-powered aircraft normally cruise at altitudes high above the airspace occupied by birds, they must pass through this zone during take-off and landing. Some military aircraft, however, fly for miles at less than 1500 feet AGL thereby extending the time they are likely to be in airspace occupied

by birds.

Strike rates vary seasonally, but are highest in North America during post-breeding migration (Table 4). At this time (late summer and fall) bird populations are largest as a result of the year's progeny being added to the adult segment. The bird-aircraft problem is widely distributed across the nation as well as the calendar (T ble 4). About 80% of the 1974-1977 strikes occurred in the southeastern (36.5%) and southwestern (43.1%) portions of the United States. These regions coincide with areas of high gull concentrations but also represent localities where air traffic is heaviest.

Frequently the bird species responsible for damage to an aircraft was not identified which makes it difficult to describe the nature of the hazard. It appears, however, that gulls represent the group of species most frequently involved. Gulls were documented as being responsible for 53 (31.2%) of the 170 USAF bird collisions that occurred during 1974 through 1977 for which species information was available. It is possible that gulls were involved in other strikes as several species are seasonally abundant in the vicinity of many air bases or along potential low altitude mission routes. Harrison and Godsey (Ref. 6) concluded that gulls were the most critical avian threat to aircraft operations on a year-round basis in Virginia. Waterfowl also represented a seasonal problem, but primarily during fall migration.

Data on civilian aircraft strikes in a number of European countries document that gulls have been involved in 53% of the strikes for which bird identification was possible (Ref. 7). In Canada, gulls were involved in 9.2 - 18.5% (mean = 14.1%) of all birdstrikes that occurred during a five-year period. Civilian data for Air Canada during 1972 and 1973 indicated that 16.4 and 26.8%, respectively, of their birdstrikes were caused by gulls. Although gulls comprise only six (6.8%) of the 88 species of birds that have been recorded from Canadian birdstrikes, they were involved in about 22% of them. Because of the wide range of habitats in which gulls can be found, they occur at almost every airport location in Canada (Ref. 7). Even prairie airports have problems with inland nesting species of gulls, such as the Franklin's Gull (*Larus pipixcan*).

Since gulls as a group are more frequently involved in bird-aircraft collisions than any other group of birds, they were selected as subjects for the study described in this report.

Examples of other Approaches for Diminishing the Problem

Environmental conditions at, or adjacent to, some air bases have contributed to the hazardous conditions (Ref. 10). This is due, in part, to the tendency for airports to be constructed in areas often attractive to birds. Elimination of favorable habitats, food sources, and other airfield features attractive to birds has been recommended by several investigators. Many air bases have implemented some of these practices, such as closing dumps and landfills on or within three miles of the base, and have successfully reduced the number of strikes. Nevertheless,

the danger of colliding with a bird remains a serious problem. The various devices and schemes used at airfields have little effect on the presence of birds away from the base but yet within the approach, departure or low altitude routes of aircraft. Other approaches are required for predicting where and when potentially dangerous concentrations of birds will occur.

Birds are highly mobile and travel daily between foraging and roosting areas or between distant localities during migration. Such movements periodically bring large numbers of birds into airspace simultaneously used by aircraft. The exact pattern of bird distribution is subject to considerable variation and is related to such things as habitat availability. Nevertheless, general patterns of distribution of some species can be predicted with reasonable accuracy as to time and place of occurrence. Seasonal changes in bird abundance have significant influence on the probability of a strike occurring. Solman (Ref. 1) concluded that migration in Canada involved several billion birds, including up to 100 million ducks, 8 million geese, several hundred thousand cranes and swans, and hundreds of millions of birds smaller than ducks. Much of the migration occurs at night, at altitudes up to 20,000 feet. Obviously the risk to aircraft would be lessened if they did not simultaneously occupy airspace used by these birds.

Several investigators (Ref. 11, 12) have used radar to monitor the intensity of nocturnal migration and to develop procedures for forecasting the density of bird migration according to predicted weather conditions. Diversionary tactics or rescheduling of flights on the basis of such evidence has successfully reduced the number of strikes at some air bases. In Canada, for example, one or two military CF-104 aircraft were lost annually prior to the use of radar forecasts. Subsequent to adoption of this procedure, no aircraft have been lost.

Changes in the airport environment and radar forecasts represent effective measures for reducing the number of birdstrikes (Ref. 13). Radar is a valuable tool for indicating what is happening at a particular point in time and space. Some regional predictions are possible based on past correlations between radar data and seasonal weather patterns. An effective system for coping with bird hazards to aircraft away from air bases requires a procedure that provides long-range forecasts of when and where birds of various species may occur in sufficient numbers to raise the probability of a strike above acceptable levels. Integration of these three methods (habitat manipulation, radar, long-range predictions of bird occurrence) could result in a significant reduction in the number of strikes. Schedules and routes resulting in the least risk of exposure to birdstrikes could be selected by consulting detailed bird migration summaries for critical species, such as gulls. Obviously factors other than bird concentrations must be considered when selecting routes and recognition of the value of scheduling aircraft around bird concentrations does not negate the importance of these factors (e.g. obstacles such as radio towers). However, decision-makers should consider revising their priorities to

include avoidance of high risk bird densities. A change of attitudes must accompany implementation of bird hazard information so that it will be considered as seriously as changing weather conditions.

It is apparent that the birdstrike problem is not a single problem but a multifaceted one influenced by aircraft and mission type, geographic locality, season of the year, and species of bird involved. A simple solution to the problem does not exist. The characteristics of the problem are not the same at every Air Force Base or along all mission routes. The approach to solving this problem must take these complexities into account. Variability is to be expected in data sets describing the behavior of animals. Because of this, large sample sizes are required before accurate predictions are possible. Presently such data sets do not exist for describing the daily or even weekly distribution of most bird species. Obtaining such data will necessitate a commitment of resources and personnel beyond that used to date (Ref. 9).

Contribution of This Study

A model that uses existing information to predict the probability of a birdstrike under particular sets of conditions is critical to any forecasting scheme.

The report describes statistical procedures for making risk predictions based on the number and kinds of birds present or likely to be in a given area, the number of aircraft that will be flying in that same area, and the prior birdstrike history for the area of concern. Given this information it is possible to predict the probability of a strike occurring within a specific area during a particular span of time. The accuracy of this procedure is directly correlated with the completeness of each of the sets of input data listed above. If, for example, risk predictions are to be made for a specific base during a specific week of the year, then the bird data, mission data and strike data must be detailed enough to permit this degree of resolution. The data available for this purpose at this time are inadequate and so we attempted to do the best we could with what was available. One USAF Base, Langley in Virginia, for which reasonably complete strike and mission data existed, was used as an example of how the procedure would work.

This is not the first study dealing with the bird hazard problem. For several years the military, governmental agencies and private organizations have been addressing various aspects of the problem. Many reports have been distributed on the control of bird populations at airfields, bird detection, effect of birdstrikes on aircraft structure, effect of engine ingestion, and studies of bird migration. The present study is unique, however, because it shows how baseline biological data, USAF mission data and strike records can be used during the early stages of route planning to reduce the probability of birdstrikes occurring.

During the course of the study we evaluated each of the so-called data banks containing gull distributional data. This

report and the Preliminary Report (Ref. 14) provide an analysis of each of the most complete data sets. The only data set that provided nation-wide coverage and data for every month of the year was the banding data. Because of this, use of banding data as an indicator of bird distribution has been emphasized in this report. The other data sets are provided in summarized form as they may prove valuable in making hazard predictions for restricted areas or only portions of the year (e.g. parts of December and January in the case of Christmas Count data).

Eventually the type of distributional information presented for gulls should be provided for all species of birds that are frequently involved in strikes. Incentive for using this type of information should result from the savings in dollars and possibly human lives that will be realized by avoiding heavy mission schedules in regions where risk levels are predicted to be seasonally high. Such a procedure could maintain the number of birdstrikes at a level more acceptable to the USAF. It will be difficult, however, to prove a cause and effect relationship between implementation of the techniques recommended in this report and any subsequent decrease in the frequency of birdstrikes.

The results from this project have been published in two parts: an Interim Report in 1978 and this document. Portions of the data contained in the Interim Report have been reproduced in the Final Report. The remaining material has been cited in this document but it will be necessary for the reader to consult the original source for details (Ref. 14).

II. METHODS

Because of their frequent involvement in birdstrikes and their regular occurrence near some air bases, gulls were selected as appropriate subjects for testing the feasibility of predicting where and when bird concentrations may be high enough to raise the probability of a birdstrike beyond acceptable risk levels.

Six sources of gull data were evaluated as to their appropriateness for describing seasonal distribution patterns of all gull species within North America. These were: 1) band recovery data, 2) National Wildlife Refuge Quarterly Reports, 3) Christmas Bird Count summaries, 4) published records of gull occurrence, 5) personal observations and solicited reports from regional reporters, and 6) breeding data from the Colonial Bird Register at Cornell University. An important problem inherent in all of the available data sets is that none were formulated specifically for addressing a problem of this type or magnitude. Project-specific data are necessary before accurate forecasting is possible.

Band Recovery Data. This data set was provided by the U.S. Fish and Wildlife Service Bird Banding Office and the Canadian Wildlife Service. It included all band recoveries for gulls that had been reported through July 1977 (n = 74,255 recoveries). These data were examined as one set composed of all years for which information was available, and also on an annual basis for each of the six most recent years (1972-1977) included in the

available data. The set comprised of all years was accepted as most useful at this time because it provided 1) a larger sample size, 2) better coverage of the entire nation, and 3) a means of avoiding the high variability that occurs when annual samples are compared.

A band recovery is a report submitted by a person who finds, or otherwise encounters, a bird that carries a metal band bearing a number unique to that individual bird and the address of the Fish and Wildife Serivce. The band is applied by an investigator working with the species, usually at a breeding colony, and most often when the gull was a juvenile.

Various problems are associated with using recovery data for describing the distributional trends of a species. Of particular importance to this study, is the fact that the probability of a band being recovered is highest where large numbers of people live or recreate. Therefore it may appear that some areas with suitable habitat have very few gulls when, in fact, the data reflect the scarcity of people at that locality to report bands. We have no way of compensating for this bias on a nation-wide basis.

The banded proportion of the gull population represents a very small part of the total population. This is complicated further by the fact that very few bands are recovered. In most cases, the recovery rate is less than 6%, and this includes instances where investigators are actively retrapping birds and obtaining recovery data within breeding colonies. For species where investigators are not conducting such efforts, recovery rates are usually less than 1%. By combining data for all recovery years into one data set, some of the variability associated with small sample sizes has been spread over a span of time and is less noticeable.

In spite of these limitations, banding data provided the most complete coverage for the nation and for the various months of the year. Therefore, this data set was selected as being the most representative form of distributional data available at this time and it is recommended for use in the proposed model. The amount of information available for each gull species is not uniform. This reflects somewhat the amount of attention various species have received from researchers. In other instances, it is partially associated with the population size of the species, the remoteness of its breeding grounds, or the fact that migration routes and winter ranges are in areas where band recovery is less likely. Table 5 lists the number of recoveries for each species that was included in our sample.

National Wildlife Refuge Quarterly Reports. Four times per year, Managers at each U.S. Fish and Wildlife Service Refuge provide a summary of the wildlife using their respective refuges. This information, in the form of use-days per species, is computerized and maintained by the U.S. Fish and Wildlife Service. Theoretically, the data provide an indication of the abundance of each gull species at the various refuges during each three-month quarter of the year. The accuracy of the data, however, frequently reflect the interest at the Refuge Manager in nongame

species, such as gulls. In some instances, the figure provided appears to be based on actual population surveys while in others it is an armchair estimate, at best, that is used repeatedly year after year.

This data set provides an estimate of the number of gulls that used a specific area (i.e. refuge) over a 90-day quarter. An indication of the number of gulls present per day was obtained by dividing the quarterly total by 90. This figure was construed as being indicative of the number of gulls present in that area during any day of that particular quarter. Obviously, such daily averages are inaccurate, as gull distribution cannot be expected to be uniform throughout a 90-day period. Nevertheless, this was the only procedure available to us for rendering this data set useful in our attempts to map gull distribution on the basis of the kinds of information available.

The results obtained from using this data set were quite different in most cases from those derived from banding data. Because of the better resolution provided by banding data (monthly as opposed to quarterly) and the problems associated with evaluating refuge estimates, we recommend that the refuge data not be used in bird hazard predictions.

A number of Refuge Managers also submitted detailed reports to us on the number of gulls present at their refuges. Such information was not uniformly available for the refuges and so cannot be used in a nation-wide analysis. Had it been available, this would have been an extremely valuable tool for mapping the distribution of the various gull species.

Christmas Bird Count Summaries. These data are accumulated by birdwatchers across the country during portions of December and January only. The counts provide an indication of the actual number of gulls, and other birds, present at over 1000 localities scattered across the nation. In contrast, banding data provide only an index to the proportion of the population that may be present. The Christmas Bird Count reports used in this study were extracted from those published by the National Audubon Society in American Birds. Christmas Count data for 1972 through January 1977 were analyzed as a group and also on an annual basis. The data gleaned from Christmas Bird Counts from all parts of the United States amounted to about 9.5 million gull reports.

In evaluating the results from this analysis it is important to keep in mind that: (1) the accuracy of gull numbers reported during some Christmas Counts is subject to question as every participant is not capable of accurately estimating the numbers of birds in large concentrations; (2) there is a chance of the same gulls being counted more than once in regions where count localities are in close proximity to one another; (3) coverage is not uniform; and, (4) many count areas are selected because of the large numbers of birds gathered there rather than providing a random sample. Each count covers an area 15-miles in diameter.

Christmas Count data represent the best available inventory of birds from across the nation during this portion of the year (about 2 weeks). Because of its limited seasonal coverage, it

was less important in this study than banding data. The analysis provided could be used, however, to address specific problems at some bases. Similar types of data should be available for all parts of the year and for all regions of interest to the Air Force.

Published Records and Colonial Bird Register Data. All of the major ornithological journals were searched and pertinent gull data extracted. The resulting data set provided inadequate coverage for the nation and failed to give comparable data for the various species. This data set was not summarized for the report.

Recent data resulting from a series of surveys of seabird colonies provided some useful information and an indication of the size of the various breeding populations of a number of gull species present. Information contained in the Colonial Bird Register (Cornell University) also was analyzed for this study but coverage was inadequate for our purpose. The CBR data set does not contain data from all portions of the breeding ranges of the various species North American Gulls. It does contain, however, information for most of the areas having large breeding populations. A summary of this data set was not prepared for this report.

Personal Observations and Regional Reporters. We visited a number of localities across the United States and consistently recorded the number of gulls observed. Additionally, bird-watchers were encouraged to provide us with accountings of their gull observations. A number of persons faithfully provided us with very useful information. These data have given us a means of comparing the actual number of gulls present within particular regions with that predicted on the basis of our banding data analysis. Our comparisons show that it is possible to accurately predict where the largest numbers of gulls will occur.

None of the data sources currently available are suitable for accurately describing the nation-wide range of a group of nongame species, such as gulls, on a daily, weekly, or for that matter, a monthly basis. Each of the data sets is incomplete, contains inaccuracies, and, furthermore, complications exist with respect to obtaining the data. Very few journals publish frequent accounts of the number of gulls or other species of birds present in various parts of the United States. Those that publish distributional material regularly, e.g. American Birds, emphasize unusual records rather than commonplace information on the number of individuals present daily, weekly, or monthly. The reasons for private organizations not assuming this burden are understandable because of the high costs involved. It is more difficult, however, to understand why federal agencies continue to ignore the importance of a national data bank for such information. Until a suitable system is developed, banding data stand out as the best tool we have for describing nation-wide distributional trends. In using such information, we must remain cognizant of the biases associated with its collection.

Analytical Procedures for Bird Data

All of the data sets were stored on computer tape in a format resembling that used by the U.S. Fish and Wildlife Service Bird Banding Office. This necessitated development of a routine for converting some forms of data, e.g. Colonial Bird Register data, to this format. Preliminary analysis was performed by a unique computer program (Ref. 15) that sorts and plots large quantities of data. Computer processing of banding data has been described by Cowardin (Ref. 16) and Davenport (Ref. 17), but the program developed for this study is unique in the kind of data listing, the kind of data mapping, and the kinds of statistical procedures provided. It is possible to sort data according to a variety of interest subjects, including species of bird, age, banding locality, date, age within date, and a variety of other combinations. This report concentrates on the results from data sets being sorted on the basis of month, and in some cases, by year and month of recovery. In most instances the amount of data available are insufficient for describing gull distribution across the nation on a more frequent basis, i.e. weekly or daily. Improvement of the data set through a series of intensive inventories would improve the resolution of the analysis.

Besides sorting the data, the computer plots each recovery according to geographic coordinates (latitude and longitude) on a map of North America (19° to 59°N latitude; 52° to 125°W longitude). The map is a Miller cylindrical projection (a modified Mercator projection) and was prepared from maps 6 and 7 in the Area Outline Series of the U.S. Army Corps of Engineers. On this map the spacing between meridians is constant, but the spacing between parallels increases with latitude. This is taken into account in the computer plotting of points. Great circle distances also were considered during plotting of all locality data. The FORTRAN computer program was developed and run on an IBM 360/67 computer.

Each gull report is positioned on the map to within 41.4 miles (66.6 km) longitude, and from 47.0 to 34.1 miles (75.6 to 54.9 km) of latitude (from low to high latitudes, respectively). This is as accurate as the computer is capable of plotting the data on a map of this scale because of the spacing of the computer printer (10 characters/inch of horizontal line, and 6 lines/inch vertically). Increased plotting accuracy is possible on regional maps of any area of interest (e.g. Alaska) but this necessitates new programming for each map scale.

Subsequent to computer processing, the investigators manually calculated the number of gulls reported each month in what we designated as geographical Zones. These are 6°-square blocks that are serially arranged across North America in checker board fashion (Figure 1). Each Zone was assigned two letters, one for each axis, for identification purposes. Latitudinal rows are indicated by A' through G' whereas longitudinal columns are represented by A through M. Each Zone is composed of four equal-sized Quadrats that are numbered 1 through 4 (clockwise, starting at the upper left corner) within each Zone. The number of gulls

reported per Quadrat also was calculated. These figures increase the resolution of analysis by showing where gulls might be concentrated within each 6°-square Zone. Obviously gull distribution is not uniform within a Zone or within a Quadrat as it is dependent upon habitat availability. Both of the sorts described above could be performed by computer, but at this stage of the project the programming effort would have outweighed the time required to conduct the sorts manually.

The numerical and proportional data calculated for Zones were used to graph and map seasonal distribution of all gulls, regardless of species. The resulting maps or phenograms provide a generalized impression of monthly changes in gull distribution across the United States.

For use in determination of risk levels to aircraft and comparison of seasonal gull densities, we calculated the proportion of each month's recoveries that were reported from each Zone. This information is used to depict the relative abundance of gulls in each Zone. An assumption was made in the case of banding data, that the proportion of the banded sample recovered in each Zone is equal to the proportion of the national gull population that frequents that Zone. We realize that this assumption is invalid because of several biases associated with collection and use of band recovery data. Nevertheless, given the choices available to us at this time, this procedure appears to provide the most accurate measure of nation-wide patterns of gull distribution.

The actual number of gulls reported for each Quadrat was retained and plotted on maps for each month in the case of some data sets. This procedure provided an indication of the distribution of recoveries within each Zone. In most cases, however, the sample sizes are too small to justify their use in strike predictions. Graphs were prepared for each Zone having 0.2% or higher of the total gull recoveries. Each graph depicts the proportion of all recoveries reported in a particular Zone per month as well as the proportion of each Zone's monthly total that was reported per Quadrat.

For the purpose of this report, no attempt was made to interpret gull distribution in detail beyond that provided in the various maps and graphs. The level of analysis is designed to be applicable in the decision-making processes associated with reducing the number of gull-aircraft collisions rather than contributing to answering basic scientific questions about gull distribution. The maps and graphs provide flight planners and others with the basic information they require about gull distribution in order to use the bird hazard prediction model included in this report. Site-specific information about gull movements may be important supplemental information for air bases and should be supplied as needed.

Analysis of Strike Data.

U.S. Air Force data on birdstrikes were obtained for 1974 through 1977. These data provide a comparison between the seasonal density of gulls within each Zone and the frequency of

bird-aircraft collisions in that Zone. The strike data presented include all strikes, not just those involving gulls. Similarly, the data covered the entire 24-hour day, not just the hours when gulls are normally active. This procedure was followed because many of the USAF reports lacked specific information on the species of bird involved, time of day, etc.

Three levels of analysis were conducted on the strike data: (1) the frequency of strikes were summarized according to altitude of occurrence (Table 3); (2) the distribution of strikes within the various Zones is described (see Interim Report, Ref. 14); and, (3) the same procedures used to depict patterns of gull distribution were used to show the proportion of each month's total strikes that occurred within each geographic Zone.

Hazard Prediction Model.

A model was developed for the calculation of bird hazard potential at any geographical locality for which appropriate data exist. At this time, geographic Zones were used as the available information on missions flown, strike rates and bird distribution are not adequate for a finer-grained analysis. The model is based on the assumption that there is a multiplicative relationship between the density of birds, the frequency of aircraft missions, and the number of strikes that occur. Three types of input data are essential: (1) a measure of bird abundance; (2) prior information on the number of strikes in that same area; and, (3) a measure of the amount of air traffic within the area. The accuracy of predictions resulting from this model will correspond to the accuracy of each set of input data. It is essential, therefore, that attempts be made to improve the quality of data available for this purpose. The model is described in detail in the text.

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III. RESULTS

ANALYSIS OF GULL DATA

The available gull data were subjected to four levels of analysis: (1) the band recovery data for all gull species were sorted by month and the actual number of recoveries plotted by geographical coordinates; (2) the monthly proportion of the gull population represented by each data set was calculated and mapped by Zones and Quadrats to show seasonal trends in gull movement across the nation; (3) the percentage of all gulls occurring in each Zone was graphed to indicate their monthly distribution and relative abundance within each of a Zone's four Quadrats; and (4) the distribution of each of seven gull species was analyzed and mapped for each month of the year according to the proportion of the population occurring in each geographic Zone.

Three of the data sets analyzed provided sufficient information to warrant graphic treatment. These were (1) band recovery data; (2) National Wildlife Refuge data; and (3) Christmas Bird Count reports. The other forms of data that were collected during this study were considered inadequate for showing nationwide patterns of gull distribution. As a result, they are not discussed in detail in this report. A brief narrative is provided to introduce the visual presentation of results pertaining to each level of analysis.

A. Numerical Summary of Band Recovery Data.

Computer displays showing the geographic location of each banded gull recovered during January through December were included in the Interim Report (Ref. 14). The data presented were for all species of gulls and for all years for which banding data were available. The complete data set also was sorted and mapped by species for each month for all years combined (Figure 1A-L in this report) and for individual years (see Interim Report). During our initial efforts to predict the hazards gulls pose to aircraft, it was decided that the data set for all gull species combined would be emphasized. This approach is justified because it is the density of gulls, regardless of species, occurring in particular geographical areas that result in collisions with aircraft. At the present state of the art, predicting where and when gull concentrations reach proportions dangerous to aircraft is of more immediate importance than determining which species of gull may be involved. It is important, however, to have all gull species regularly occurring in the United States adequately represented in the data base.

The amount of band recovery data for each gull species is disproportionate because some kinds of gulls have been studied more intensively than others. As a result, some species that may contribute to the gull problem in particular regions (e.g. Franklin's Gull) are poorly represented in the band recovery data set (Table 5). Analysis of banding data alone will not show the

extent to which such species are seasonally hazardous to aircraft. Other types of site-specific data may have to supplement the banding data for describing distributional patterns but in the case of Franklin's Gull, none of the available data sets (e.g. published records, Refuge data, etc.) contain sufficient information for this purpose. A detailed study of this species is needed since it poses a serious problem to aircraft using bases in the northern Great Plains.

The distribution of symbols on the computer-generated maps or phenograms (see Ref. 14) gives an impression of the changing distribution of gulls during the year. In general, there is a more restricted pattern during winter and summer when the birds are on the wintering and breeding ranges, respectively. Conversely, spring and fall (pre- and postbreeding, respectively) are periods of more widespread distribution. The computer maps (Ref. 14), while showing the number of band recoveries reported across the Nation, fail to indicate the proportion of the sample population occurring in each Zone of the United States during each month. This level of analysis is described in the following section.

B. Summarized Gull Distribution Accordin, to Zones and Quadrats.

As background information, the general breeding range (Ref. 20) of each of the eight gull species for which there were more than 100 band recoveries (Table 5) is presented in Figure 2A-F. These maps indicate the parts of the continent where each of the species is concentrated during the breeding season. Seasonal movements are directed toward and away from these regions.

Four types of information are emphasized in this section of the report: (1) Maps and a summary graph showing the proportion of each month's band recoveries reported (all years combined) from each Zone (Figures 3A through 4L). (2) Maps and a summary graph based on National Wildlife Refuge data showing the proportional distribution of gulls per quarter-year (Figures 5A-D, and 6). (3) Graphs portraying the seasonal distribution of gulls within each Zone (Figure 7D'B-F'H) for which National Wildlife Refuge data were available. Similar graphs of the band recovery data were provided in the Interim Report (Ref. 18). (4) Maps showing the proportion of all gulls reported during Christmas Bird Counts for the years 1972 through 1977 in each Zone (Figure 8A & B).

1. Monthly distribution summarized by Zones.--Figure 3A through L displays the proportion (%) of the total number of banded gulls reported that particular month from each 6°Zone. The extent to which gulls occur in each Zone during all months is displayed in Figure 4. All available band recovery data were used in the preparation of these figures. This procedure provides a generalized display of where banded gulls have occurred during approximately the last two decades.

Long-term banding data tend to moderate the effect of relatively recent changes in gull distribution. Data for the Oklahoma region provide a good example of this since published

distributional data document the occurrence of thousands of gulls in that State during winter while simultaneously verifying that the great increase in gull populations is a fairly recent event. Band recovery data from this area during the winter period (Figure 3A & B), however, fail to support this observation because very few Ring-billed Gulls and Franklin's Gulls from the northern Great Plains breeding population are included in the banded sample.

Monthly changes in gull abundance are particularly noticeable in some areas and demonstrate the extent to which risk might change, either increase or decrease, over time. By examining the population estimates for a particular Zone, for instance D'J, it is possible to visualize the seasonal changes in regional gull abundance and also envision how such changes will ameliorate the gull-aircraft problem. Zone D'J also provides a good example of the usefulness of Quadrat data. In this case, all of the recoveries are from Quadrat 1, the NW one-fourth of the Zone, rather than farther from the coast. This is to be expected as it is more likely that banded gulls will be recovered by people along beaches than at sea. However, this recovery pattern is also influenced by the fact that most gulls occurring in this region are littoral rather than pelagic and hence occur more frequently along the coastline. At any rate, the Quadrat information can be used as an indication of how gulls are distributed within each Zone.

An alternative to combining band recoveries from all years into a single sample for analysis, as done in the preceding section, is to use short-term data such as those accumulated during a single year or season to predict patterns of distribution. To test the feasibility of using small, more easily obtained data sets, we sorted the band recovery data by year and compared the distribution of recoveries from each month. The maps for January through December data for each of the years 1972 through 1977 are contained in the Interim Report (Ref. 14). The variability between years is expressed primarily in the proportion of the annual sample for each month that is found in a particular Zone. Thus, although monthly data from any contemporary year might be indicative of where gulls occurred that month, the proportion of existing gulls that could be in any given area, as opposed to some other area, might be grossly underestimated by this method. Furthermore, as sample sizes become smaller the amount of variability in results increases.

We conclude, therefore, that use of band recoveries covering a long span of years provides a better indication of what proportion of the gull population can be expected at a given location and when to expect it. The best resolution possible with existing data is at the monthly level.

2. National Wildlife Refuge data.--The refuge data were treated in the same fashion as the banding data. Maps showing the proportion of the total monthly population reported from each Zone are provided in Figure 5A-D. Each of the four maps is from one three-month quarter of 1975. The refuge data are not detailed enough to justify analysis by other than a monthly basis.

The maps indicate how the gull population is distributed about on the various refuges but this is not necessarily synonymous with the nation-wide pattern of gull distribution. Manned refuges do not occur with equal frequency in all parts of the annual range of the various gull species. As a result, regions like the Great Lakes, are poorly represented in the data set. It is not apparent from the refuge data that approximately 250,000 Ring-billed Gulls and Herring Gulls breed in the Great Lakes Region. Figure 6 combines the data for all four quarters and depicts the proportion of the total sample that occurred in each geographic Zone.

The quarterly distribution of gulls within each Zone was examined by the same procedure applied to the band recovery data. The proportion of the Zone's sample reported from each Quadrat is indicated in Figure 7D'B-F'H.

The refuge data provide a better indication of the number of gulls that migrate through the Great Plains than was provided by band recovery data. The occurrence of Franklin's Gulls, for example, is well documented in several areas through sight observations by refuge personnel whereas very little banding data are available for this species from any region.

In its current form, however, the refuge data set appears inadequate for use in calculating the risk gulls present to low-flying aircraft throughout the United States. Better resolution and greater accuracy are expected from use of band recovery data.

3. Christmas Bird Count data.--The combined data for all Christmas Counts conducted during the last five years (through January 1977) are presented in Figure 8A & A.

C. Monthly Occurrence of Gulls within Each Zone and Its Quadrats.

In the preceding analysis, we examined gull distribution on the basis of the proportion of the seasonal population, as represented by the recovered banded sample or refuge observations, that occurred in various parts (i.e. Zones) of the nation. The result is a phenology of gull distribution within each 6°-square Zone that has produced at least 0.2% of the total available data. This provides an estimate of the proportion of the gull population that might be expected to occur in a particular Zone during any month or quarter (banding and refuge data, repectively) of the year.

Figure 4 displays the frequency of occurrence of band recoveries from each of the Zones, and Figure 6 provides similar information for the refuge data. Zones without any recoveries were omitted from these graphs. An arbitrary decision was made to select Zones having at least 0.2% of the recoveries of graphing purposes. A separate graph was prepared for each Zone. The resulting figures for the band recovery data were included in the Interim Report (Ref. 18). Figure 7 contains the refuge data.

ANALYSIS OF USAF BIRDSTRIKE DATA

Birdstrike data for 1974 through 1978 were obtained from the USAF. The thoroughness of the information available for each strike varies considerably. The reasons for the irregularities

in the data set are several but they cluster around the fact that it is often difficult for crew members to know exactly when some strikes occur and/or to identify the species of bird involved. As a result, many of the records lack one or more pieces of important data, such as species of bird, geographic location, time of day, date of occurrence, etc. Because we could not accurately identify all of the collisions that involved gulls, it was necessary to examine the strike data as a total package. This procedure prevents a reasonably precise determination of the risk gulls, as opposed to other species, present to aircraft across the nation. The analysis does provide, however, information useful in establishing the maximum level of risk that could exist because of gulls. At this time it appears that gulls, on the average, are involved in 30-50% of the strikes that occur across the nation. At some locations, however, their frequency of involvement may be much higher. Thus until more complete nationwide strike data are available, it will be necessary for risk predictions based on the present data to be adjusted either upward or downward according to knowledge available for specific bases on the extent to which gulls have been involved in strikes.

The available strike data for all years are summarized by month in Figure 9. Birdstrikes are most frequent during fall migration (September - November) and spring migration (March - April). They are lowest during the breeding and wintering periods of the year. Figure 9 shows, however, that considerable variation exists in the number of strikes reported in any one month during 1974-1978.

The strike data were examined by the same procedures applied to bird distribution data. The Interim Report (Ref. 14) contains maps showing the monthly distribution of all USAF birdstrikes within the continental United States. These same data were then converted to the proportion of the total recoveries per month that occurred in each geographic Zone (Figure 10).

IV. PROCEDURE FOR PREDICTING GULL-AIRCRAFT HAZARD LEVELS

To evaluate the potential hazard of gulls to low flying aircraft, we have developed a model whereby the probability of k number of strikes occurring within a unit of space and time can be computed. The model is based on the assumption that there is a multiplicative relationship between the density of birds, the density of aircraft (i.e. number of sorties, hours or transitions flown) and the number of strikes that occur. This is expressed in the following formula, with the condition that $f \geq b$:

$s = b \times f \times c$, where:

s = the number of bird-aircraft strikes in a given area in a given time,
b = the proportion of a bird population present in a geographical area at the given time,
f = the number of USAF sorties, hours or transitions flown in the given area during the given time, and
c = a proportionality constant.

A change in either bird density in the area or mission frequency would result in a corresponding increase or decrease in birdstrike probability. The likelihood of a strike is zero if either no birds or no aircraft are present in the critical airspace.

Four types of information are critical to the development and testing of the applicability of this model. If one of the data sources is missing or incomplete, the predictions are meaningless for practical purposes and cannot be tested. We have available only one of the four types of necessary information at this time. It is imperative that all input data collected by Air Force personnel in the future be as complete as possible, and available for incorporation into such a model. The kinds of data needed for the model are: (1) numerical values for the seasonal distribution of all gulls occurring in the continental United States (provided by this study), (2) the number of missions flown and the numbers of take-offs and landings at continental USAF Bases for each aircraft type, (3) the number of bird (gull)-aircraft strikes that occur, and (4) the geographic location of strikes at a level of precision comensurate with the size of the desired prediction zone. All strikes should be reported (damaging and non-damaging) because any strike is a potentially dangerous one. For each strike, the following information should be recorded whenever possible: the species of bird, location coordinates, time, altitude, nearest AFB, and the type of plane. Without question, collection of such information is difficult at times and impossible at others, but the more complete the record, the greater the accuracy of strike prediction.

Various other factors may influence s, the number of strikes that have occurred or are likely to occur, but cannot at this time be incorporated into a model due to a lack of data. For example: (1) the model assumes a random distribution of birds

and aircraft which in reality can be influenced greatly by concentrated food sources, preferred mission paths, etc.; (2) large aircraft should possess a greater probability of colliding with a gull than small aircraft simply because they sweep more airspace; (3) the speed and flight altitude (e.g. low level, take-off, etc.) of an aircraft probably alter the effectiveness of any evasive movements attempted by gulls; (4) the species of gull involved and the amount and type of prior experience they have had with fast moving aircraft will influence their alarm responses to aircraft in motion; and (5) the proportion of flight time that is spent by aircraft within airspace frequented by gulls obviously affects the probability of a strike. The influence of each such factor must be measured before it can be included in the model. At this stage of model development, however, it is important that the principal data sets (e.g. mission and strike statistics) be upgraded before less influential factors, such as the above-mentioned, are incorporated into a prediction model.

We have been provided with aircraft movement and birdstrike data for Langley AFB in Virginia which we will use to illustrate the procedure for calculating gull-aircraft strike predictions. Table 6 details the sortie and birdstrike data available for Langley. In calculating mean numbers of sorties and strikes, it is desirable to use as many years as possible for which both types of data are accurate and complete. Since the species of bird involved in many strikes is unknown, mean numbers of strikes should be computed by using not only those incidents in which gulls were known to be involved, but also those strikes involving an unknown species of bird. Gull relative abundance figures are listed for all Zones that had at least 0.02% of the total band recoveries in Table 7. For ease in following the Langley example, its Zone's relative monthly gull abundance figures have been listed separately in Table 8.

In attempting to construct a year-round representation of the gull-aircraft strike hazard at a given base, a straight forward, stepwise procedure can be followed. Briefly, the basic steps involve computing: (1) the constant c, (2) a predicted s, and (3) $P(k/d)$ or $P(k)$, the probability of given strike rates or strike numbers, respectively.

The equation $s = b \times f \times c$ allows us to calculate a Zone-specific, month-specific proportionality constant (c) based on data available from recent years. Substituting a mean number of strikes ($\bar{s}$) for the given month and Zone, a mean number of missions ($\bar{f}$) for the given month and Zone, and the mean relative abundance of gulls ($\bar{b}$) for the same area and time (from Table 6), c is readily calculated.

<u>Example</u> - Langley AFB (Zone D'I), January:

$\bar{s}$ = 2.5 strikes

$\bar{f}$ = 1751 sorties

Example (cont.)

$$\bar{b} = 5.92 \text{ gulls (monthly proportion)}$$

$$2.5 = 5.92 \times 1751 \times c$$

$$c = 0.00024 \text{ strikes/gull/sortie.}$$

If bird density or mission frequency changes and one wishes to predict the effect on number of strikes, f, c, and b are now known factors and a new s can be computed easily.

Example - Langley AFB (Zone D'I), January:

Varying predicted (hypothetical) number of sorties (f) for the year 1980 -

If $f_{1980} = 1700$,

$$s_{1980} = 5.92 \times 1700 \times 0.00024 = 2.42 \text{ strikes}$$

If $f_{1980} = 2100$,

$$s_{1980} = 5.92 \times 2100 \times 0.00024 = 2.98 \text{ strikes.}$$

It should be pointed out that s is merely a best estimation of the number of strikes that have occurred or that will occur. The probability of a given number of strikes occurring is calculated by means of another equation for which an accurate estimation of s is essential.

To compute the probability of k or more gull-aircraft strikes, the Poisson model is used. This model is helpful in estimating probabilities for unlikely, random phenomena where there are large numbers of trials (e.g. missions) present. For our purposes, the Poisson equation can be written:

$$P(k) = \frac{e^{-s}s^{k}}{k!}$$

or

$$P(k/d) = \frac{e^{-r}r^{k}}{k!}$$

where:

$P(k)$ = the probability of k number of events (e.g. strikes) occurring in a unit of space and/or time,

$P(k/d)$ = the probability of k number of events occurring per d number of trials (e.g. sorties) in a unit of space and/or time

e = the base of natural logarithms (2.71828...)

s = the best estimate of predicted number of strikes, and

$r = s/f$ = the best estimate of predicted strike rate (e.g. strikes per 1000 sorties).

If $P(k/d)$ is to be calculated, the variable r must be expressed in the same terms as k/d, i.e. strikes per d number of sorties (or hours, or transitions). For example, if the probability of k number of strikes occurring per 1000 sorties (d) is to be computed, r should be calculated as: $r = \frac{s}{f} \times 1000$.

<u>Example</u> - Langley AFB (Zone D'I), January:

s_{1980} = 2.70 strikes (from previous calculations)

f_{1980} = 1900 sorties (hypothetical)

d = 1000 (arbitrary selection)

$r_{1980} = \frac{s}{f} \times 1000 = \frac{2.70}{1900} \times 1000 = 1.42$ strikes/1000 sorties.

Following is an example of the use of the Poisson equation for computing $P(k/d)$, the probability of a given strike rate occurring.

<u>Example</u> - Langley AFB (Zone D'I), January:

r_{1980} = 1.42 strikes/1000 sorties

$$P(0 \text{ strikes/1000 sorties}) = \frac{e^{-1.42}(1.42)^0}{0!} = 0.24$$

$$P(1 \text{ strike/1000 sorties}) = \frac{e^{-1.42}(1.42)^1}{1!} = 0.34$$

$$P(2 \text{ strikes/1000 sorties}) = \frac{e^{-1.42}(1.42)^2}{2!} = 0.24.$$

Table 9 illustrates the results that can be obtained from the Poisson equation when adequate input data are provided. It can be readily noted that July is generally a low risk month, whereas August is a relatively high risk month for gull-aircraft strikes at this locality. Since there is a high probability (79%) of no strikes occurring during 1000 sorties in July, flight planners may want to schedule a greater number of missions during that month and fewer during August.

By using the probabilities that are provided in Table 9, the values in Table 10 can be derived. For example, in January the probability of more than zero birdstrikes occurring per 1000 sorties is: $P(k/d > 0) = 1 - P(k/d \leq 0) = 1 - 0.24 = 0.76$. Similarly, the probability of more than two strikes occurring per 1000 sorties is: $P(k/d > 2) = 1 - P(k/d \leq 2) = 1 - (0.24 + 0.34 + 0.24) = 0.18$.

The alternative to computing $P(k/d)$, a strike rate probability, is to calculate $P(k)$, the probability of an absolute number of strikes occurring in an upcoming year for which a given number of sorties has been hypothesized.

<u>Example</u> - Langley AFB (Zone D'I), January:

s_{1980} = 2.70 strikes

f_{1980} = 1900 sorties (hypothesized)

$$P(k=0) = \frac{e^{-2.7}(2.7)^0}{0!} = 0.07$$

$$P(k=1) = \frac{e^{-2.7}(2.7)^1}{1!} = 0.18$$

$$P(k=2) = \frac{e^{-2.7}(2.7)^2}{2!} = 0.25.$$

These probabilities indicate the likelihood of a given number of strikes occurring in 1980 if the hypothesized 1900 sorties are flown. Table 11 lists the values we computed for arbitrarily chosen f values across the year at Langley AFB. The figures in Table 11 can be used to compute the likelihood of more than k number of strikes occurring. This simple mathematical operation is illustrated on the preceding page; the resultant values for this example are tabulated in Table 12.

For any given month and Zone, a table similar to Table 13 can be computed when the basic input data are available. This arrangement may be useful in obtaining an impression of how the *likelihood of a particular strike number* changes as the number of sorties is decreased or increased. A separate s (probable strikes) value must be computed for each hypothesized f value.

<u>Example</u> - Langley AFB (Zone D'I), January:

If f_{1980} = 1700,

s_{1980} = 5.92 x 1700 x 0.00024 = 2.42

If f_{1980} = 1800,

s_{1980} = 5.92 x 1800 x 0.00024 = 2.56

If f_{1980} = 1900,

s_{1980} = 5.92 x 1900 x 0.00024 = 2.70

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If f_{1980} = 1700:

$$P(k=0) = \frac{e^{-2.42}(2.42)^0}{0!} = 0.09$$

<u>Example</u> (cont.)

$$P(k=1) = \frac{e^{-2.42}(2.42)^1}{1!} = 0.22$$

$$P(k=2) = \frac{e^{-2.42}(2.42)^2}{2!} = 0.26.$$

Probabilities for more than k number of strikes can also be computed by using the previously mentioned simple mathematical procedure (Table 14).

Throughout this discussion, we have used the example of Langley Air Force Base for which three basic sets of input data are available: bird density, aircraft movement and birdstrike data. Unfortunately, one or more of these three types of vital information is lacking for many bases around the country. In order to accurately predict the probabilities of bird-aircraft collisions in the future, complete data sets must be compiled. As we have shown here, it is possible to compute strike probabilities with relative ease when input data are available. Such calculations could allow for eventual reductions in USAF birdstrike hazard rates.

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Table 1. Summary of USAF birdstrike data indicating the number of strikes per year that caused damage to aircraft.

Year	Number of Strikes	Total $ Loss (in millions)
1967	379	not known
1968	363	not known
1969	338	not known
1970	360	1.2
1971	383	13.5
1972	350	0.8
1973	323	24.6
1974	466	4.2
1975	399	26.1
1976	363	5.1
TOTAL	3724	$\bar{x} = 372.4$

Table 2. Frequency of birdstrikes at various altitudes (in feet above ground level).

Altitude	1968*	1969	1970	1971	Total	% Total**
0-100	77	55	41	42	215	21.3
101-500	60	40	58	39	197	19.5
501-1000	54	48	61	51	214	21.2
1001-2000	43	51	60	77	231	22.8
2001-3000	27	17	18	16	78	7.7
Over 3000	8	32	14	22	76	7.5
Subtotal					1011	
Unknown	94	95	108	136	433	
Totals	363	338	360	383	1444	

* 1968, Ref. 1; 1969, Ref. 2; 1970, Ref. 8; 1971, Ref. 3.

** refers to subtotal or the number of strikes for which altitude data were available (n = 1011)

Table 3. Altitudes at which gulls and other birds struck aircraft, 1974 through 1977 (from unpublished USAF data).

Altitude (in feet AGL)	Unknown Species	Non-Gulls*	Gulls	Total	% of Subtotal**
On ground	79	13	10	102	18.6
2-10	3	2	2	7	1.2
15-25	6	2	2	10	1.7
30	1	-	1	2	0.4
50	7	4	2	13	2.2
100-150	19	5	2	26	4.4
200-250	22	2	1	25	4.2
300-350	15	4	1	20	3.4
400-410	14	1	-	15	2.5
500-550	60	2	2	64	10.8
600	11	1	1	13	2.2
700-750	5	3	-	8	1.3
800	15	1	1	17	2.9
900-960	3	-	-	3	0.5
1000	52	8	-	60	10.1
1100-1200	11	1	1	13	2.2
1300-1400	10	2	-	12	2.0
1500-1687	34	7	1	42	7.1
1700-1800	16	1	1	18	3.0
1900-2000	28	10	1	39	6.6
2100-2250	4	-	-	4	0.7
2300-2500	14	1	-	15	2.5
2600-2700	5	1	-	6	1.0
2800-2950	2	2	-	4	0.7
3000-3100	17	1	-	18	3.0
3200	1	-	-	1	0.2
3400-3500	2	1	-	3	0.5
3900-4000	9	-	-	9	1.5
4500-4600	4	1	-	5	0.8
5000-5500	3	2	-	5	0.8
6000-6500	5	-	-	5	0.8
6700-7500	3	-	-	3	0.5
7900-8000	2	-	-	2	0.3
10000	2	-	-	2	0.3
14500-15000	3	-	-	3	0.5
Subtotal				594	
Unknown	485	39	24	548	
Totals	972	117	53	1142	

* species identified and known to be other than gulls

** includes only reports for which the kind of bird involved and altitude were recorded

Table 4. Summary of Birdstrikes by geographical location and month, USAF data for 3 years.

Continental USA*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		Totals	% of U.S. Total
					Number of Strikes										
NE															
1968	1	0	5	4	2	1	3	0	4	2	3	1		26	
1969	0	1	1	1	3	3	3	2	4	10	0	1		29	
1970	1	5	1	7	2	2	3	5	9	5	3	1		44	
1971	0	2	1	3	8	2	4	7	6	8	3	1		45	
													Total	144	13.2
SE															
1968	8	5	10	7	5	6	5	6	17	14	15	5		103	
1969	8	8	4	6	7	2	6	6	20	15	16	6		104	
1970	7	6	3	10	1	2	4	5	13	14	9	7		81	
1971	1	6	8	7	13	6	6	10	17	16	11	5		107	
													Total	395	36.5
NW															
1968	0	0	0	0	1	1	1	0	2	5	0	1		11	
1969	0	4	1	1	1	1	1	0	0	1	4	0		14	
1970	1	4	2	2	1	1	3	1	2	5	2	1		25	
1971	0	2	2	3	3	0	0	6	6	3	0	1		26	
													Total	76	7.0
SW															
1968	5	1	7	14	14	5	4	10	11	20	13	4		108	
1969	8	14	11	9	13	6	8	7	15	5	13	4		113	
1970	10	9	8	12	11	12	9	11	15	18	10	2		127	
1971	7	5	9	11	8	11	6	10	14	17	16	4		118	
													Total	466	43.1
Unknown															
1968	5	0	5	2	3	0	3	2	5	4	4	5		38	
1969	2	3	4	2	2	1	1	0	3	4	2	0		24	
1970	1	0	2	1	5	0	3	0	3	7	2	2		26	
1971	0	0	0	1	3	2	0	3	6	10	6	1		32	
													Total	120	

* foreign strikes are excluded from table but are included in totals for years presented elsewhere

Total for NE thru SW = 1081
Unknown location = 120

From Ref. 1, 2, 3 & 8

Table 5. Number of band recoveries by species, supplied by the U.S. Fish and Wildlife Service and the Canadian Wildlife Service.

Species	U.S.	Canadian	Total
Glaucous-winged Gull (*Larus glaucescens*)	9,881	7,345	17,226
Great Black-backed Gull (*L. marinus*)	783	354	1,137
Western Gull (*L. occidentalis*)	1,515	--	1,515
Herring Gull (*L. argentatus*)	25,155	7,032	32,187
California Gull (*L. californicus*)	2,179	555	2,734
Ring-billed Gull (*L. delawarensis*)	12,307	8,952	21,259
Laughing Gull (*L. atricilla*)	1,521	--	1,521
Franklin's Gull (*L. pipixcan*)	134	110	244
	53,475	24,348	77,823*
Glaucous Gull (*L. hyperboreus*)			
Iceland Gull (*L. glaucoides*)			
Mew Gull (*L. canus*)	Less Than 100 Recoveries		
Heermann's Gull (*L. heermanni*)			
Bonaparte's Gull (*L. philadelphia*)			
Little Gull (*L. minutus*)			

*this total may not agree with that used elsewhere in this report because those recoveries that lacked complete data were excluded from computer sorts.

Table 6. Langley AFB Aircraft Movements and Birdstrikes.

	Sorties			Birdstrikes*		
	1978	1979	Mean	1978	1979	Mean
Jan	1662	1840	1751	3	2	2.5
Feb	1789	1337	1563	3	1	2.0
Mar	1983	2108	2045.5	1	4	2.5
Apr	1872	2115	1993.5	1	3	2.0
May	2125	2109	2117	2	4	3.0
Jun	2136	1982	2059	1	2	1.5
Jul	1935	1768	1851.5	1	0	0.5
Aug	2329	2163	2246	2	5	3.5
Sep	1803	--	--	3	3	3.0
Oct	2268	--	--	3	--	--
Nov	2057	--	--	2	--	--
Dec	1805	--	--	1	--	--

* Birdstrikes are those involving gulls or unknown species of birds.

Table 7. Monthly Proportions of Gull Recoveries.

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A'B					6.67		26.67	26.67	20.00	20.00		
B'A	5.13	24.68	9.59	9.48	9.43	9.29	12.70	10.78	12.28	6.34	5.95	4.20
B'B		1.09		6.52	2.17	7.61	18.48	32.61	17.39	11.96	2.17	
B'C				4.49	9.27	24.72	22.75	16.29	10.39	8.99	2.53	0.56
B'D		0.39		1.93	9.27	15.06	22.78	17.37	17.76	12.36	1.54	1.93
B'E	1.50			1.50	10.60	7.58	21.21	28.79	10.60	18.18		
B'F	4.17				20.83	12.50		12.50	20.83	16.67	16.67	12.50
B'G	0.60			0.60	11.98	6.59	14.37	32.34	11.98	12.57	7.78	1.20
B'H		1.18	1.18	2.35	1.18		4.71	17.65	41.18	24.71	5.88	
B'I			4.00		4.00	4.00	2.00	18.00	30.00	28.00	8.00	2.00
B'J	5.40	0.19	0.19	1.88	5.82	7.13	10.13	21.20	27.58	14.63	5.25	0.56
B'K	0.45	0.45	0.45	3.14	8.52	3.14	5.83	24.22	30.00	14.35	6.28	3.14
B'L	1.15	1.15	1.15	2.29	2.29	2.67	3.82	23.66	31.68	21.76	5.34	3.05
B'M		3.57	3.57					17.86	57.14	7.14	3.57	7.14
C'A	8.72	12.42	7.77	4.40	3.11	3.26	7.26	6.67	9.42	9.89	18.83	8.24
C'B	0.96	3.11	2.15	17.46	12.44	7.18	23.21	11.00	5.26	8.37	6.46	2.39
C'C			0.40	6.05	8.87	19.76	28.23	13.71	5.65	12.50	2.82	2.02
C'D	7.14			7.14	14.29		7.14	21.43	14.29	21.43		7.14
C'E	0.56	0.56	1.69	4.52	14.12	9.60	15.82	20.34	10.73	16.95	4.52	0.56
C'F	1.85	0.31	2.77	9.54	10.15	11.69	12.92	14.15	10.15	16.31	7.38	2.77
C'G	1.16	1.39	1.34	2.62	5.28	10.23	17.88	30.26	13.84	8.47	5.41	2.13
C'H	0.80	0.40	0.63	1.69	11.38	9.52	17.22	30.06	12.78	9.09	4.31	2.12
C'I	0.46	0.53	1.27	1.83	5.07	5.50	19.32	25.46	19.02	14.33	5.68	1.55
C'J	1.70	1.67	2.06	1.37	6.28	9.25	17.86	21.65	17.70	11.72	6.20	2.52

Table 7 cont.

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
C'K	2.67	1.85	0.62	3.70	3.91	7.00	10.29	14.61	20.99	19.96	9.88	4.53
C'L	0.63	1.90	1.27	1.90	4.43	18.99	19.62	10.76	20.89	13.92	3.80	1.90
C'M			1.75	5.26	7.02	10.53	14.04	36.84	15.79	7.02	1.75	
D'A	15.65	10.00	6.61	7.56	3.87	3.75	3.39	8.33	11.37	7.80	12.92	8.75
D'B	1.52	1.52	4.55	9.09	10.61	16.67	15.15	6.06	28.79	3.03	3.03	
D'C	1.53	0.76	2.29		19.85	10.69	12.21	5.34	15.27	14.50	13.74	3.82
D'D	1.15	2.30	1.15	5.75	13.79	9.20	10.34	13.79	9.20	18.39	12.64	2.30
D'E			15.00	10.00	2.50	2.50	2.50	2.50	5.00	42.50	15.00	2.50
D'F	6.74	2.25	15.73	10.11	12.36	4.49	5.62		3.37	14.61	11.24	13.48
D'G	8.56	5.74	19.58	7.85	6.92	3.63	3.75	11.02	6.33	4.81	11.96	9.85
D'H	4.31	2.74	4.55	5.25	7.99	3.13	5.02	24.84	14.11	11.44	10.03	6.58
D'I	5.92	5.01	8.29	6.50	7.22	6.73	7.90	11.66	12.96	12.54	5.99	9.29
D'J	2.18	0.75	1.67	2.08	2.56	10.42	25.28	34.09	11.90	3.69	1.98	3.41
E'A	6.94	5.56	6.94	8.33	2.78	6.94	8.33	8.33	13.89	15.28	11.11	5.56
E'B	15.55	7.95	7.95	9.72	9.72	5.12	4.06	4.24	8.83	6.01	8.66	12.19
E'E	7.94	6.35	4.76	3.17	12.70	6.35	1.59		3.17	12.70	26.98	14.29
E'F	21.61	13.14	6.78	7.20	7.20	4.66	0.85	1.27	2.12	2.54	9.75	22.88
E'G	22.55	13.87	11.90	6.44	5.18	2.66	1.26	1.12	1.54	2.10	9.94	21.43
E'H	14.46	10.89	13.76	8.54	6.45	4.36	3.40	1.83	1.83	4.36	13.85	16.29
E'I	15.01	10.79	10.62	6.75	7.25	2.53	2.19	3.04	5.06	10.12	14.50	12.14
F'E	19.14	18.66	15.31	16.27	6.22	4.31	3.35		1.44		2.87	12.44
F'F	29.54	15.25	11.38	11.38	6.54	2.91	1.45	1.21	0.73	0.24	4.84	14.53
F'G	33.82	13.24	13.24	2.94	0.74	1.47	2.94		1.47	0.74	11.03	18.38
F'H	22.08	17.63	13.89	8.84	4.10	2.50	1.95	1.15	1.35	1.95	6.54	18.03
G'H	25.00	21.88	7.81	3.13		1.56	4.69	4.69		4.69	10.94	15.63

Table 8. Relative Monthly Gull Abundance in Zone D'I, Which Includes Langley AFB.

January	5.92
February	5.01
March	8.29
April	6.50
May	7.22
June	6.73
July	7.90
August	11.66
September	12.96
October	12.54
November	5.99
December	9.29

Table 9. Probability of k Birdstrikes per 1000 Sorties at Langley AFB.

	$k=$						
	0	1	2	3	4	5	6
Jan	0.24	0.34	0.24	0.12	0.04	0.01	<0.01
Feb	0.27	0.35	0.23	0.10	0.03	0.01	<0.01
Mar	0.29	0.36	0.22	0.09	0.03	0.01	<0.01
Apr	0.38	0.37	0.18	0.06	0.01	<0.01	
May	0.25	0.35	0.24	0.11	0.04	0.01	<0.01
Jun	0.45	0.37	0.15	0.04	0.01	<0.01	
Jul	0.79	0.19	0.02	<0.01			
Aug	0.22	0.33	0.25	0.13	0.05	0.02	<0.01

Table 10. Probability of More Than k Birdstrikes per 1000 Sorties at Langley AFB.

	$k>$ 0	1	2	3	4	5	6
Jan	0.76	0.42	0.18	0.06	0.02	0.01	<0.01
Feb	0.73	0.38	0.15	0.05	0.02	0.01	<0.01
Mar	0.71	0.35	0.13	0.04	0.01	<0.01	
Apr	0.62	0.25	0.07	0.01	<0.01		
May	0.75	0.40	0.16	0.05	0.01	<0.01	
Jun	0.55	0.18	0.03	<0.01			
Jul	0.21	0.02	<0.01				
Aug	0.78	0.45	0.20	0.07	0.02	<0.01	

Table 11. Probability of k Birdstrikes in f Sorties at Langley AFB.

		$k=$						
	f	0	1	2	3	4	5	6
Jan	1900	0.07	0.18	0.25	0.22	0.15	0.08	0.04
Feb	1700	0.11	0.24	0.27	0.20	0.11	0.05	0.02
Mar	2100	0.07	0.19	0.25	0.22	0.14	0.07	0.03
Apr	2200	0.12	0.25	0.27	0.19	0.10	0.05	0.02
May	2500	0.03	0.11	0.19	0.22	0.19	0.13	0.07
Jun	1800	0.24	0.34	0.25	0.12	0.04	0.01	<0.01
Jul	1800	0.65	0.28	0.06	0.01	<0.01		
Aug	2300	0.03	0.11	0.19	0.22	0.19	0.13	0.08

Table 12. Probability of More Than k Birdstrikes in f Sorties at Langley AFB.

		$k>$						
	f	0	1	2	3	4	5	6
Jan	1900	0.93	0.75	0.50	0.28	0.13	0.05	0.01
Feb	1700	0.89	0.65	0.38	0.18	0.07	0.02	<0.01
Mar	2100	0.93	0.74	0.49	0.27	0.13	0.06	0.03
Apr	2200	0.88	0.63	0.36	0.17	0.07	0.02	<0.01
May	2500	0.97	0.86	0.67	0.45	0.26	0.13	0.06
Jun	1800	0.76	0.42	0.17	0.05	0.01	<0.01	
Jul	1800	0.35	0.07	0.01	<0.01			
Aug	2300	0.97	0.86	0.67	0.45	0.26	0.13	0.05

Table 13. Probability of k Birdstrikes in f Sorties at Langley AFB during January.

				$k=$			
f	0	1	2	3	4	5	6
1700	0.09	0.22	0.26	0.21	0.13	0.06	0.03
1800	0.08	0.20	0.25	0.22	0.14	0.07	0.03
1900	0.07	0.18	0.25	0.22	0.15	0.08	0.04
2000	0.06	0.17	0.24	0.22	0.16	0.09	0.04
2100	0.05	0.15	0.23	0.23	0.17	0.10	0.05

Table 14. Probability of More Than k Birdstrikes in f Sorties at Langley AFB during January.

				$k>$			
f	0	1	2	3	4	5	6
1700	0.91	0.69	0.43	0.22	0.09	0.93	<0.01
1800	0.92	0.72	0.47	0.25	0.11	0.04	0.01
1900	0.93	0.75	0.50	0.28	0.13	0.05	0.01
2000	0.94	0.77	0.53	0.31	0.15	0.06	0.02
2100	0.95	0.80	0.57	0.34	0.17	0.07	0.02

Figure 1A-L. Monthly distribution of band recoveries for each species for which more than 1100 total recoveries exist. In each Zone designated on the map by heavy vertical and horizontal lines and letters (e.g. B'A), the percentage of that month's total band recoveries is indicated for each species. The species are indicated by initials listed on the margin: GWG = Glaucous-winged Gull; GBBG = Great Black-backed Gull; WG = Western Gull; HG = Herring Gull; CG = California Gull; RBG = Ring-billed Gull; and LG = Laughing Gull.

A. January. Sample sizes for each species are: GWG - 906 recoveries; GBBG - 41; WG - 113; HG - 1292; CG - 87; RBG - 823; LG - 51.

B. February. GWG - 1096 recoveries; GBBG - 35; WG - 114; HG - 896; CG - 57; RBG - 597; LG - 19.

C. March. GWG - 1579; GBBG - 43; WG - 82; HG - 1086; CG - 67; RBG - 584; LG - 38.

D. April. GWG - 1211; GBBG - 46; WG - 122; HG - 1234; CG - 127; RBG - 598; LG - 25.

E. May. GWG - 1410; GBBG - 89; WG - 61; HG - 1548; CG - 194; RBG - 1969; LG - 54.

F. June. GWG - 1434; GBBG - 89; WG - 65; HG - 2663; CG - 307; RBG - 1636; LG - 50.

G. July. GWG - 1818; GBBG - 149; WG - 74; HG - 4327; CG - 358; RBG - 3410; LG - 92.

H. August. GWG - 1309; GBBG - 190; WG - 74; HG - 7206; CG - 504; RBG - 5141; LG - 217.

I. September. GWG - 1691; GBBG - 150; WG - 206; HG - 4246; CG - 344; RBG - 2192; LG - 210.

J. October. GWG - 1801; GBBG - 139; WG - 138; HG - 3104; CG - 250; RBG - 1495; LG - 161.

K. November. GWG - 1350; GBBG - 86; WG - 164; HG - 2306; CG - 159; RBG - 901; LG - 111.

L. December. GWG - 814; GBBG - 53; WG - 127; HG - 1608; CG - 94; RBG - 839; LG - 85.

(Recoveries outside the range of the map are not included in these totals.)

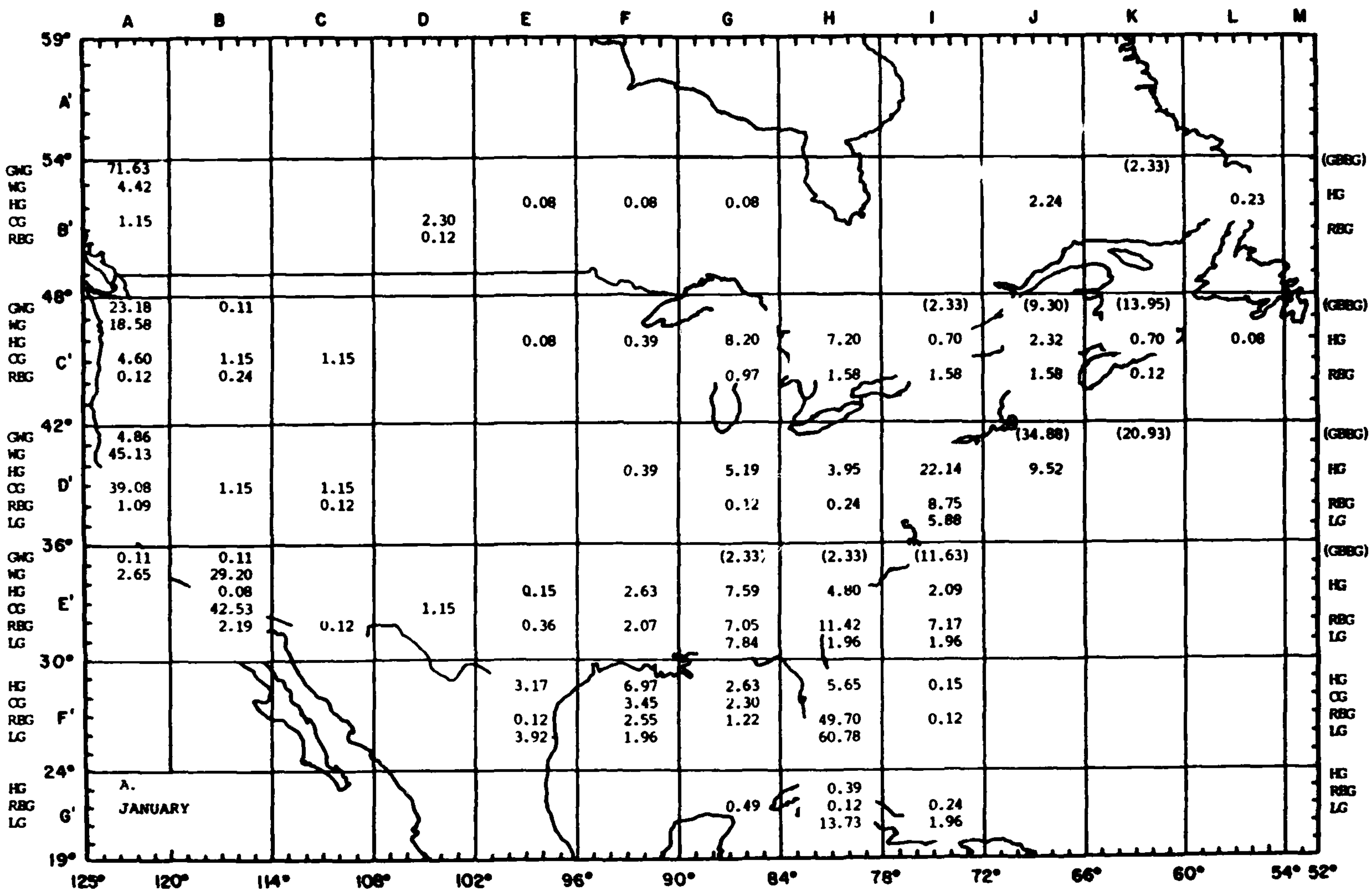


Figure 1A. January.

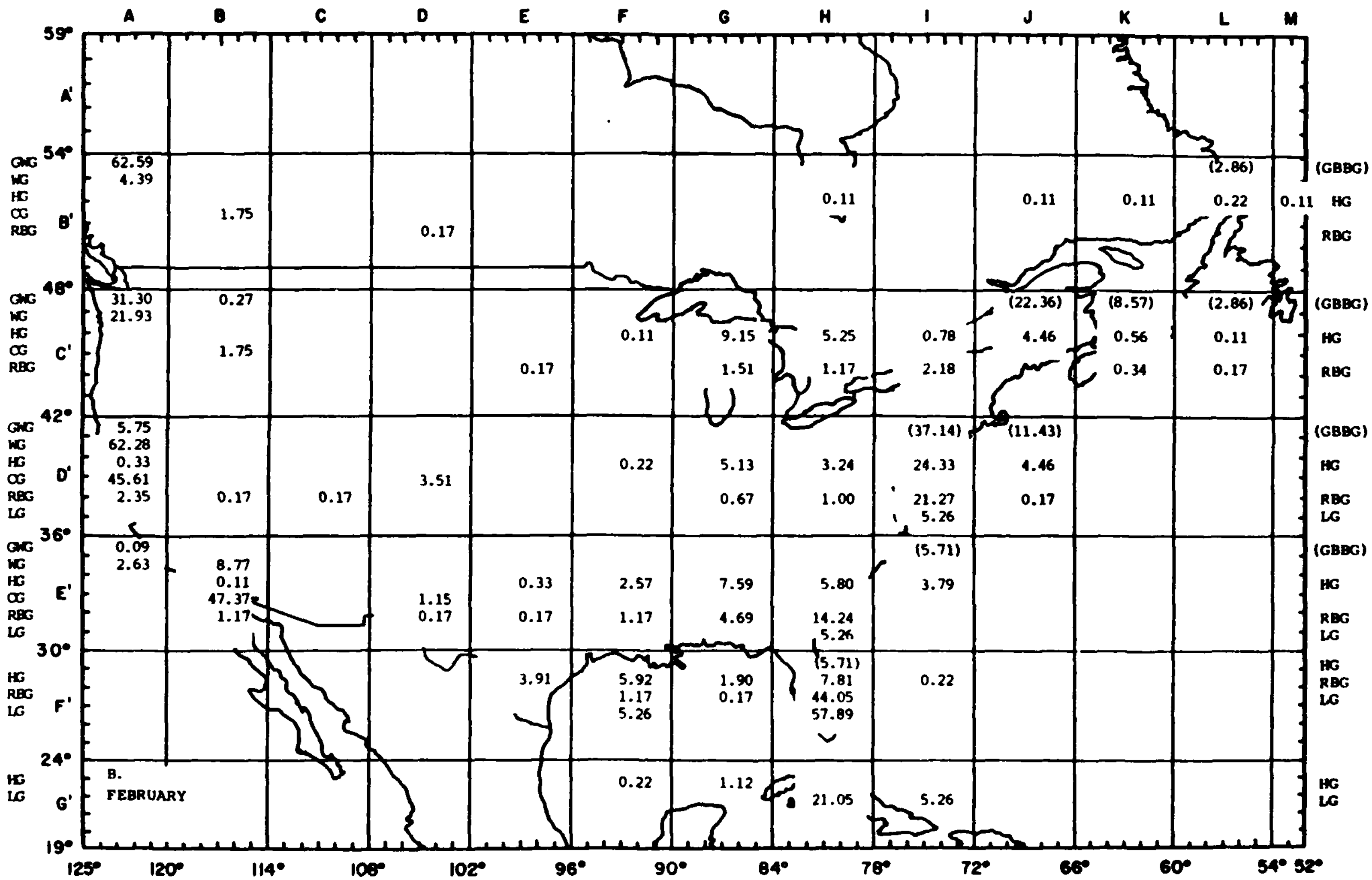


Figure 1B. February.

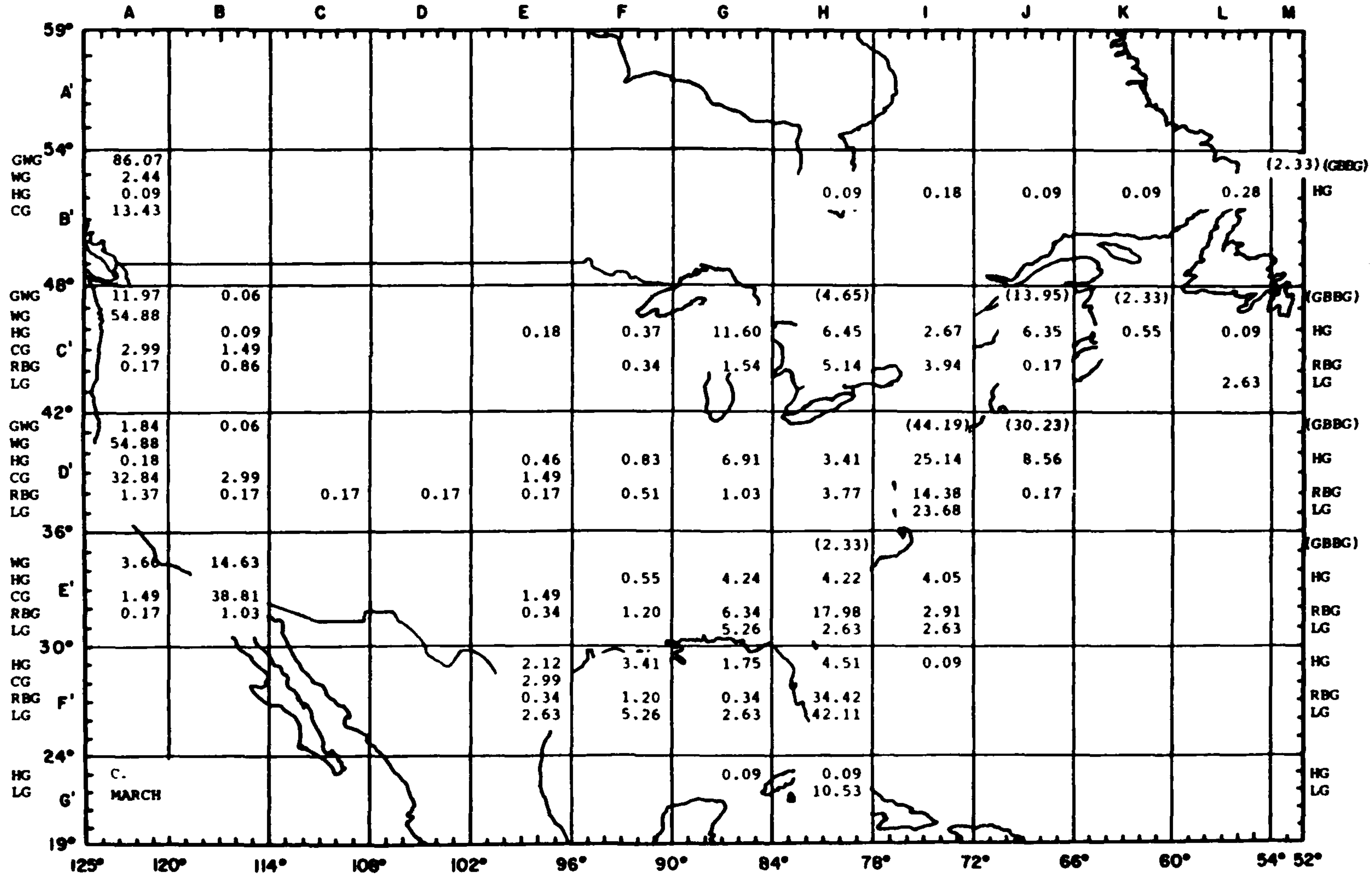


Figure 1C. March.

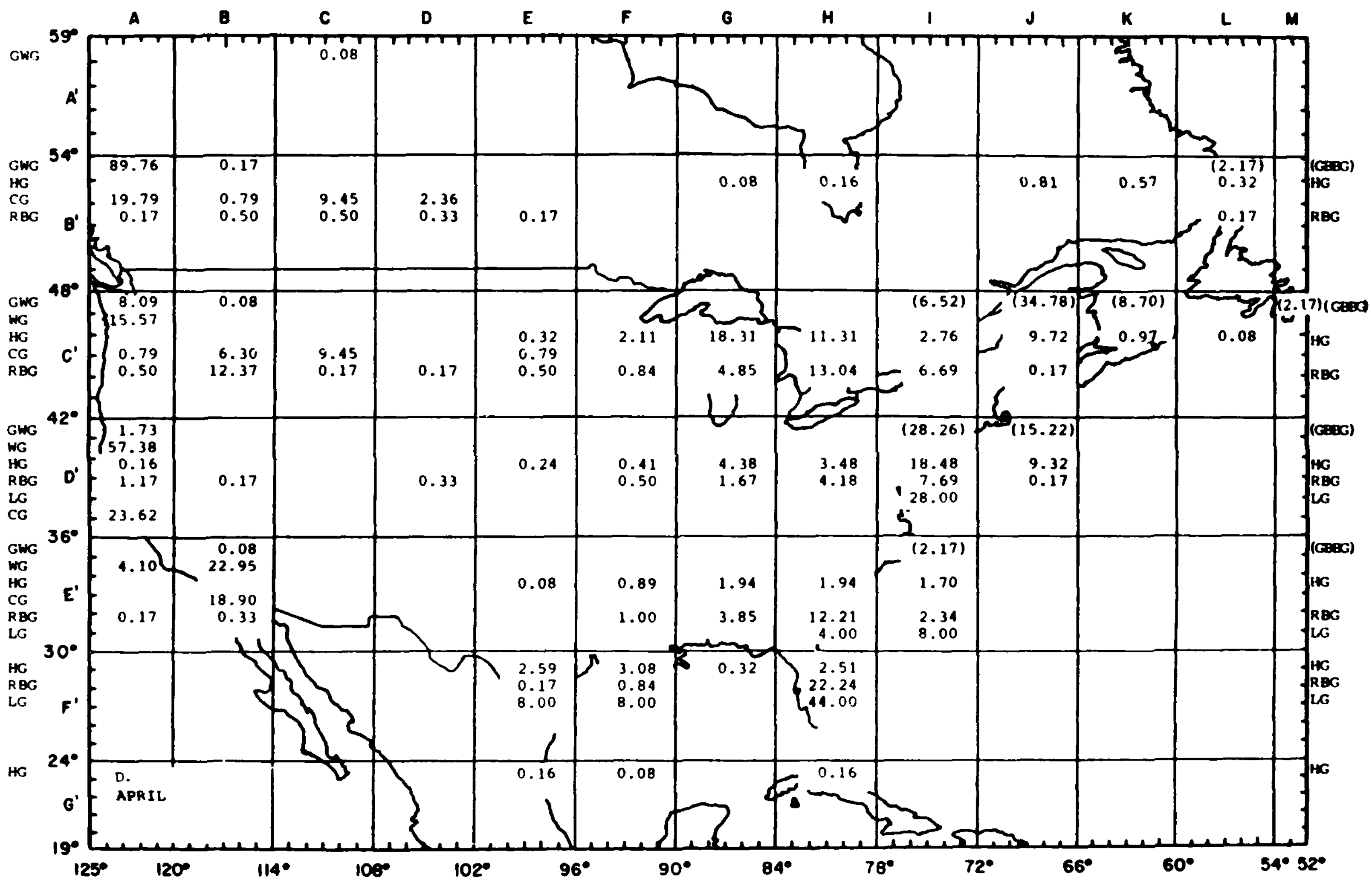


Figure 1D. April.

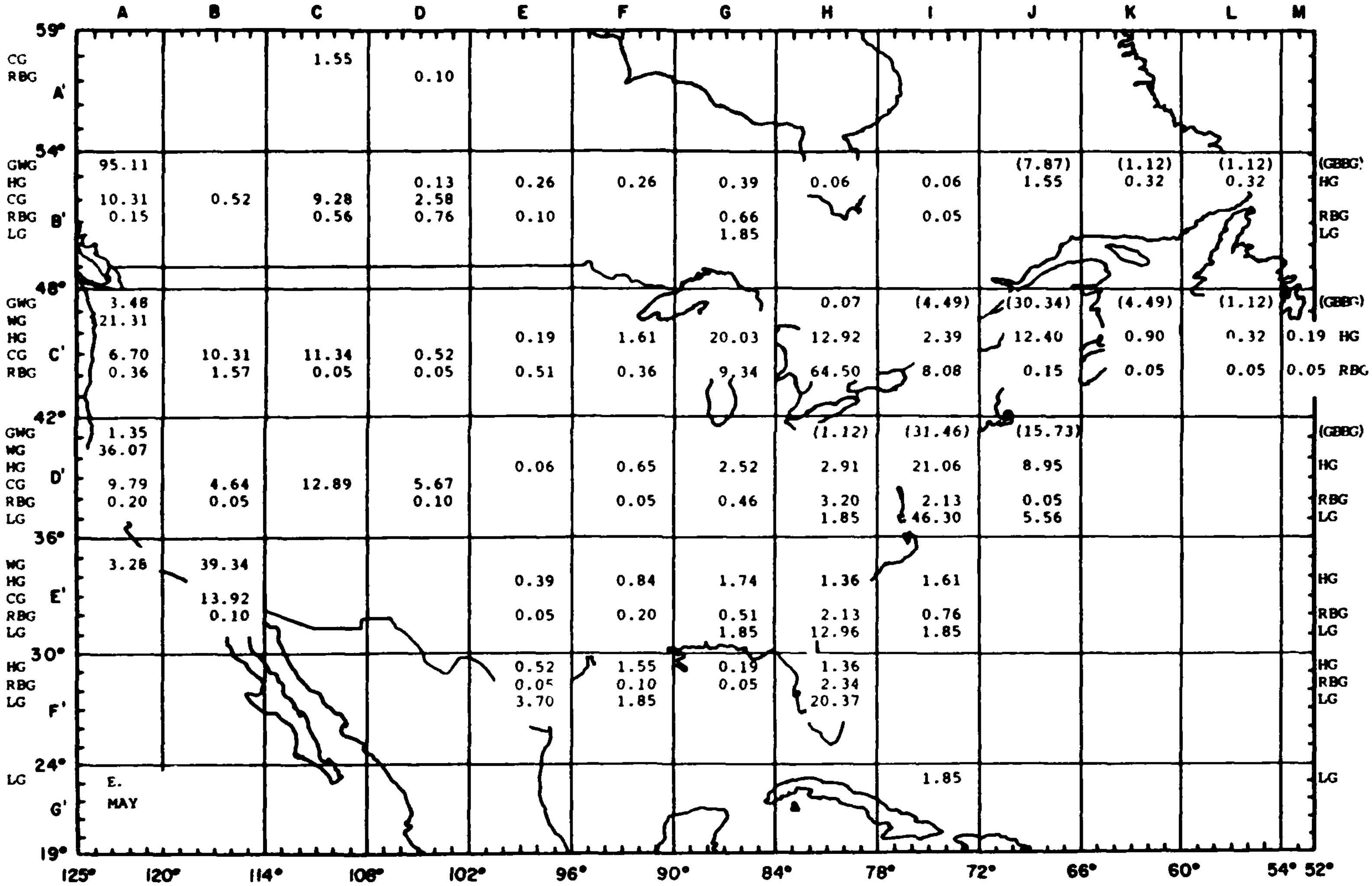


Figure 1E. May.

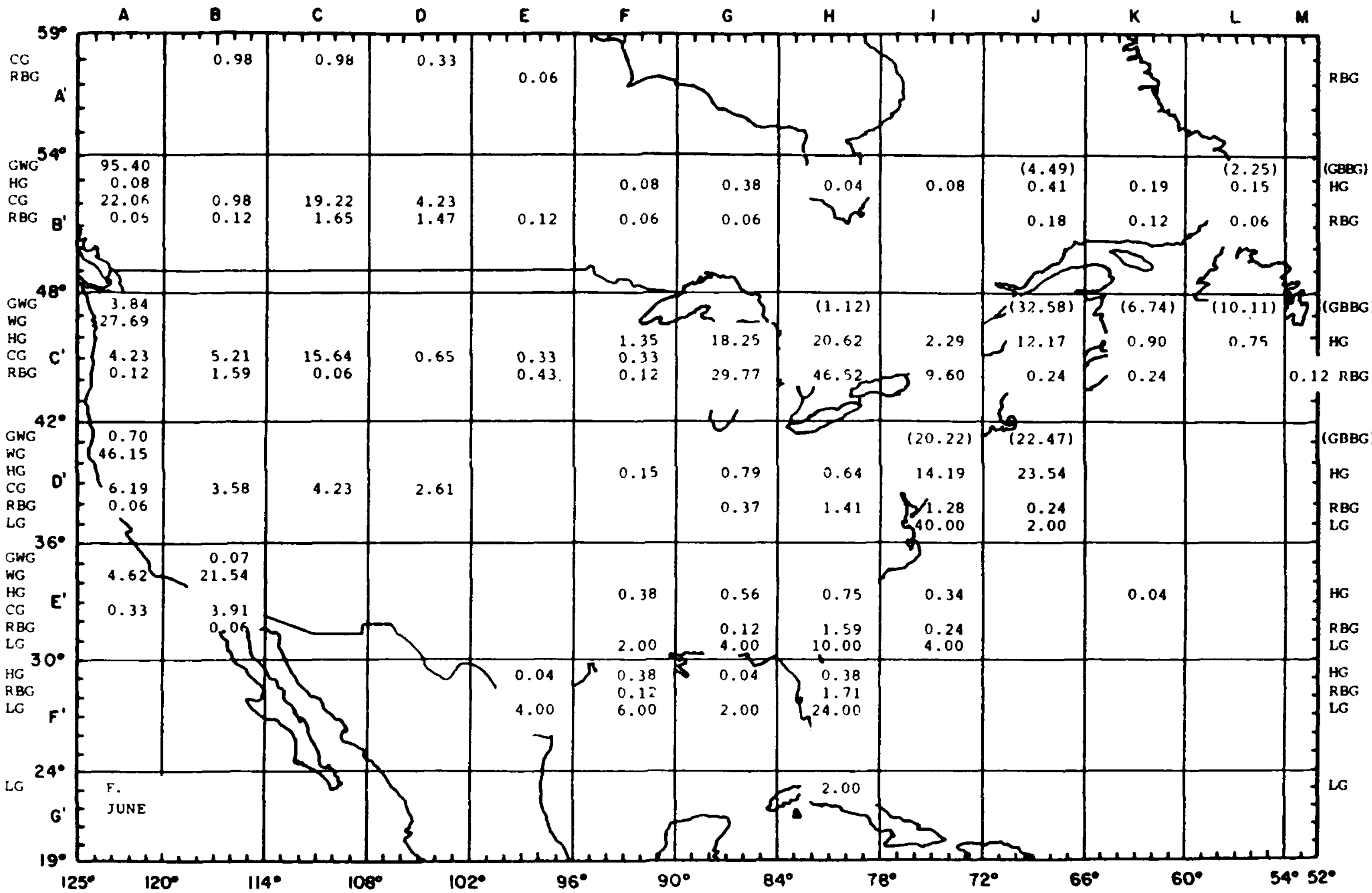


Figure 1F. June.

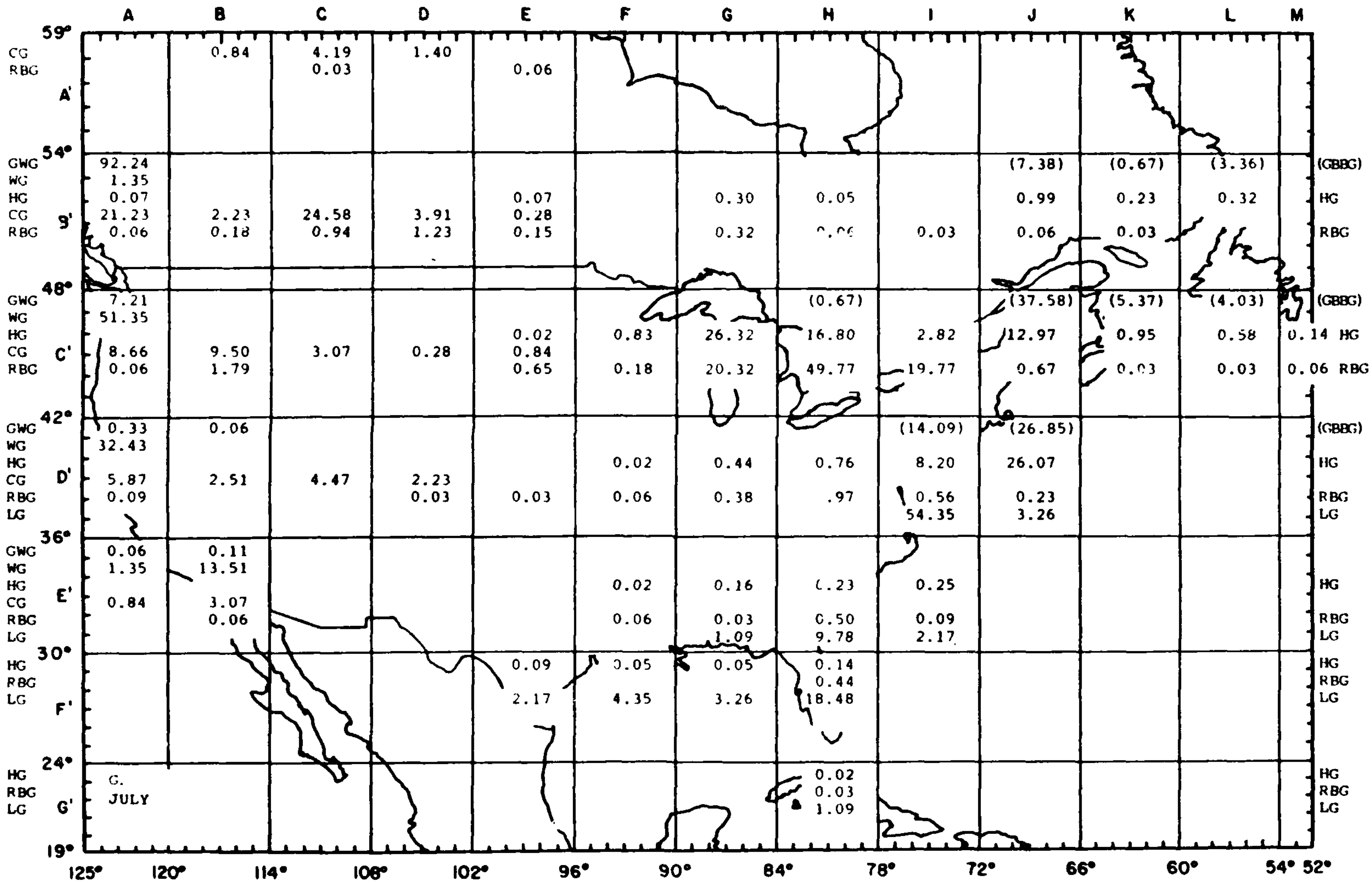


Figure 1G. July.

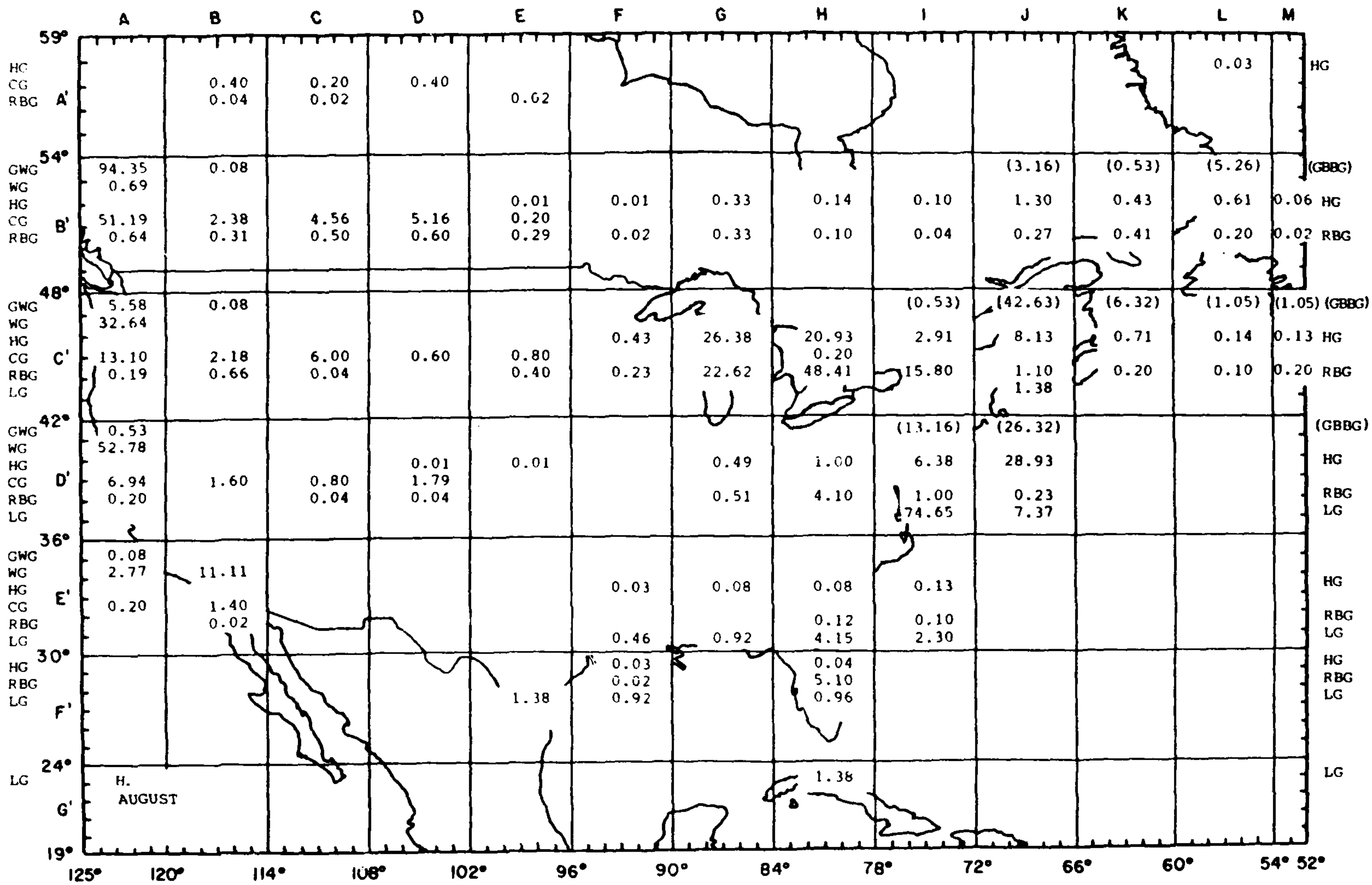


Figure 1H. August.

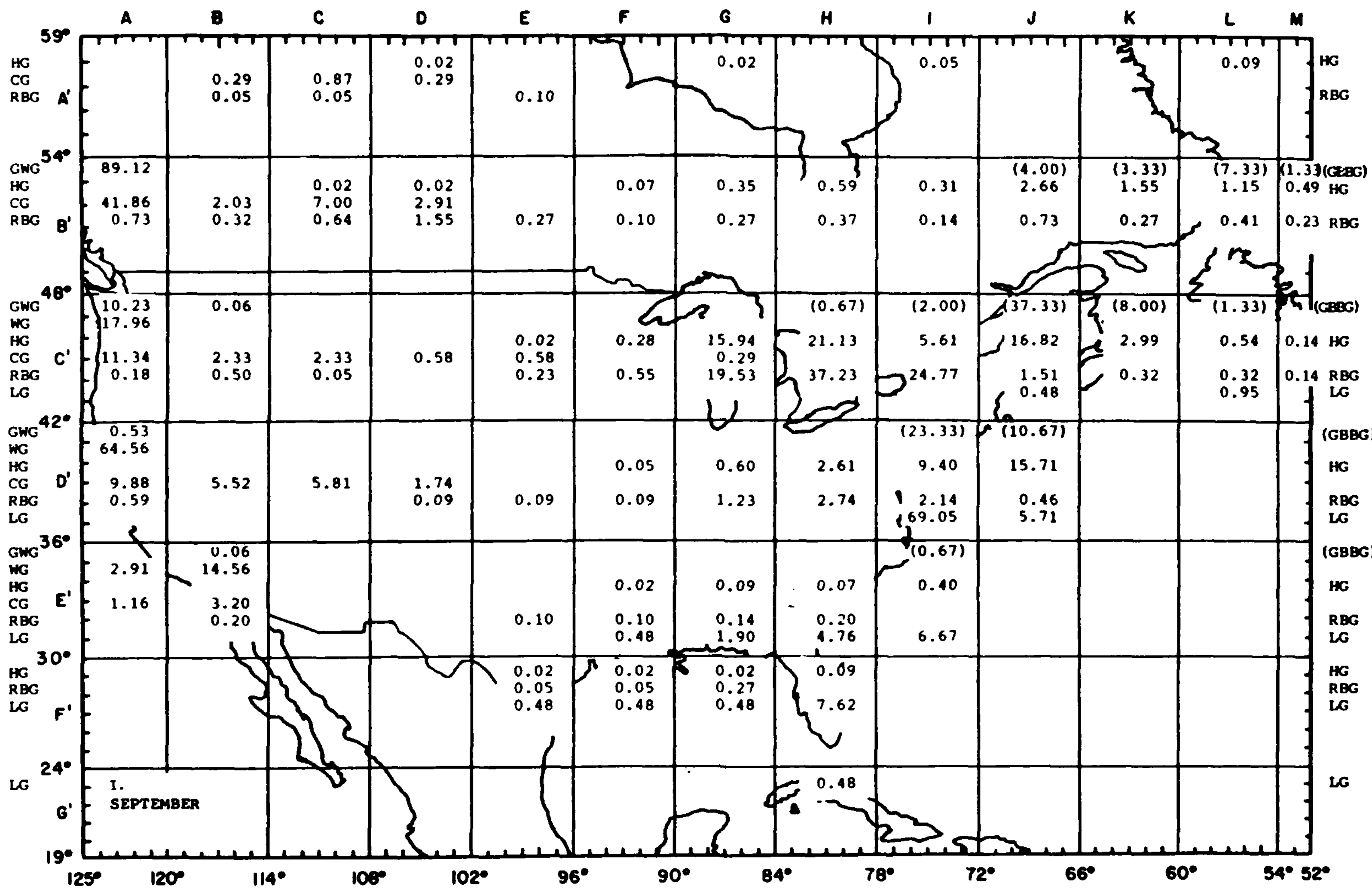


Figure 11. September.

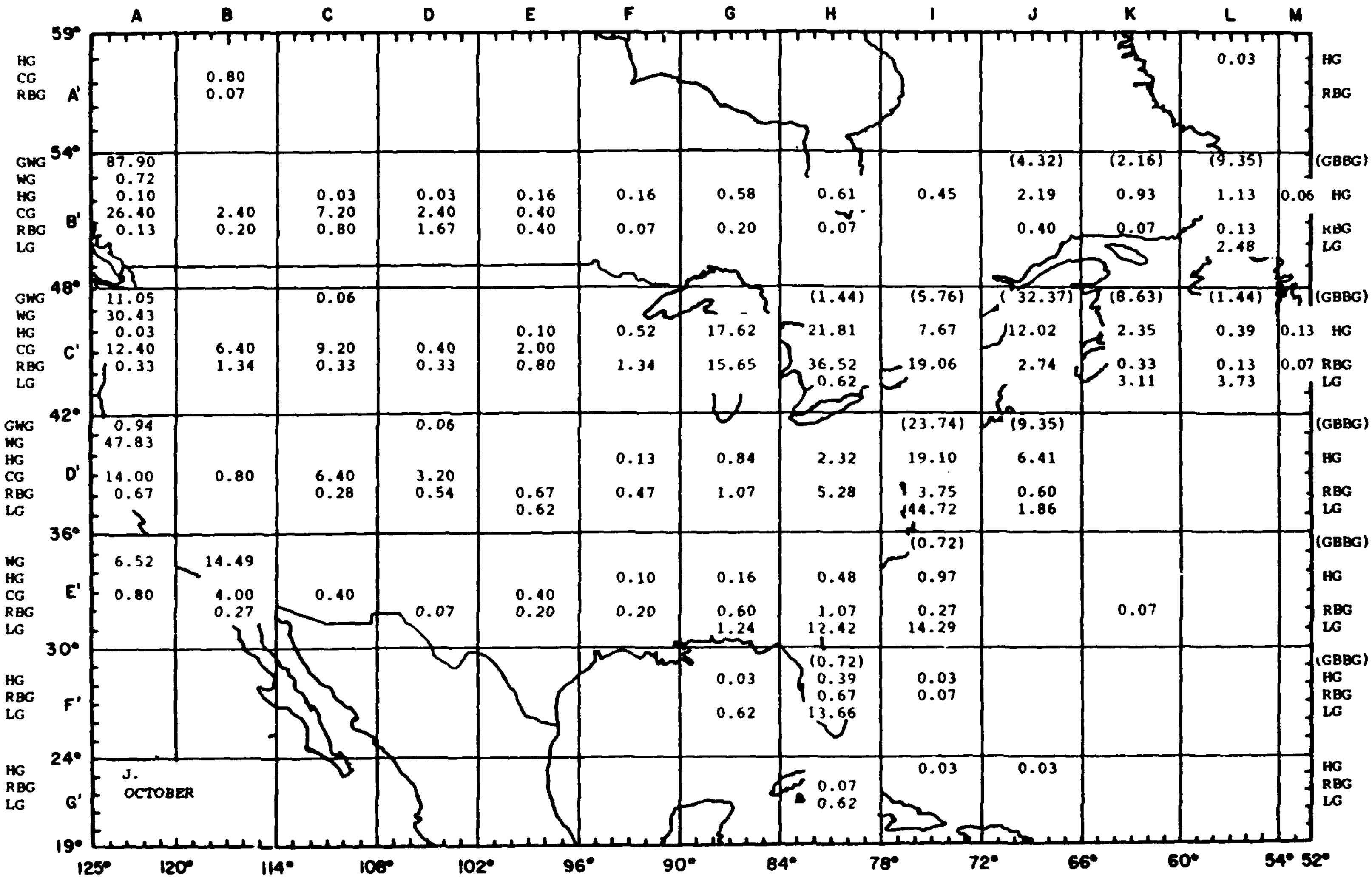


Figure 1J. October.

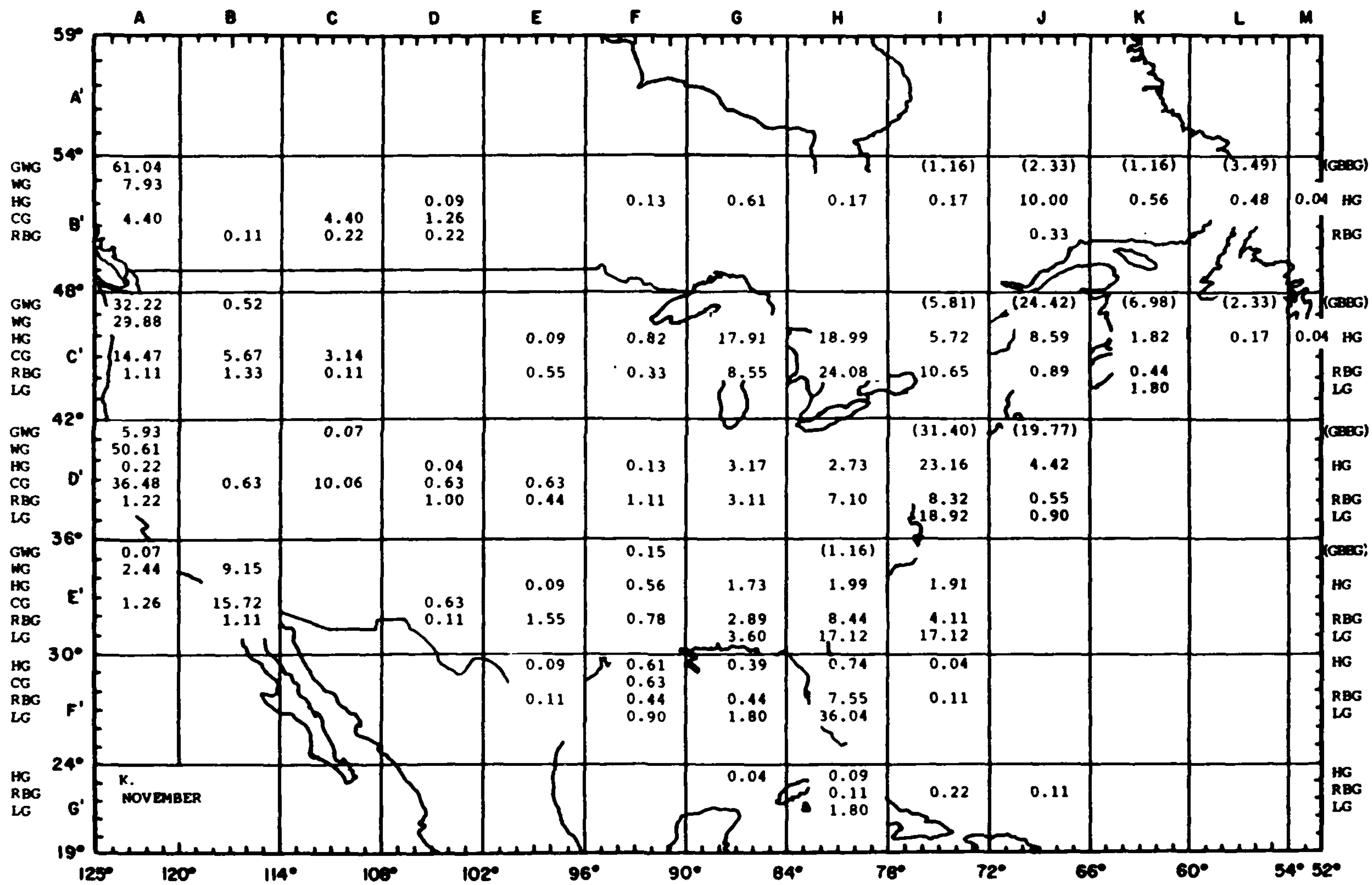


Figure 1K. November.

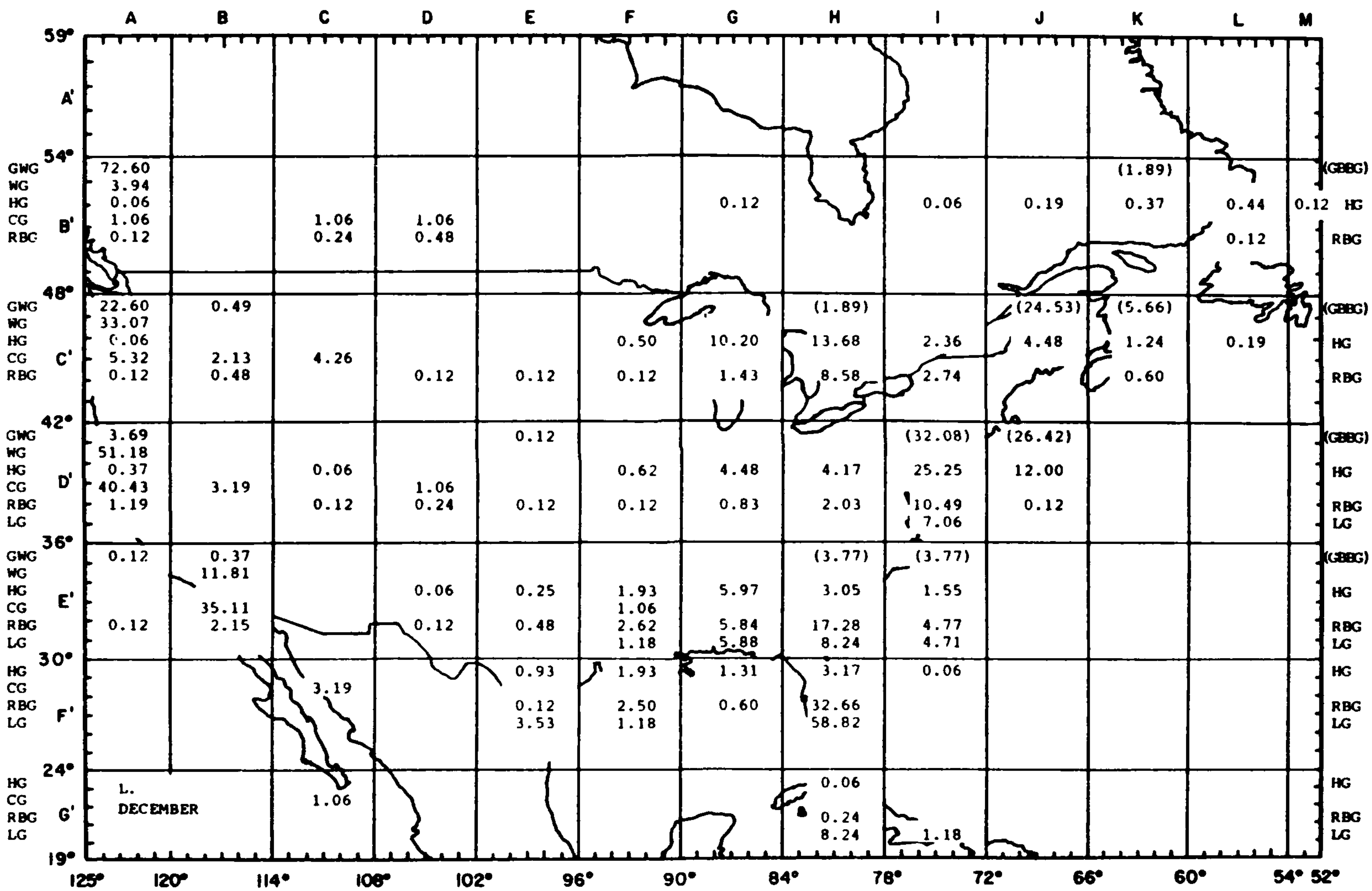


Figure 1L. December.

Figure 2A-F. Breeding ranges of North American gulls for which 100 or more band recoveries are available.

A. Glaucous-winged Gull and Great Black-backed Gull

B. Herring Gull

C. California Gull

D. Ring-billed Gull

E. Western Gull and Franklin's Gull

F. Laughing Gull

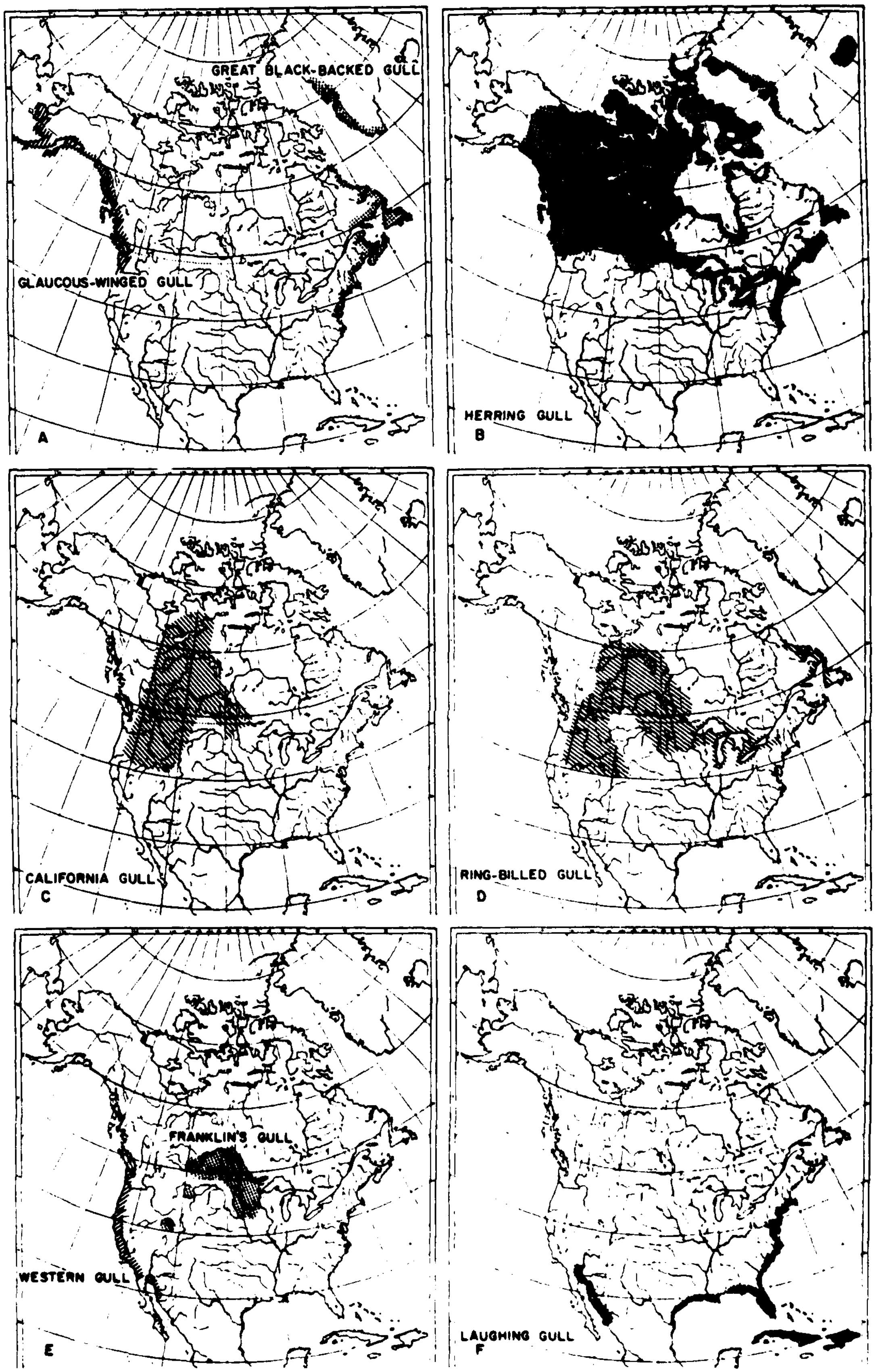

GREAT BLACK-BACKED GULL
GLAUCOUS-WINGED GULL
A
HERRING GULL
B
CALIFORNIA GULL
C
RING-BILLED GULL
D
FRANKLIN'S GULL
WESTERN GULL
E
LAUGHING GULL
F

Figure 3A-L. Percent of each month's total band recoveries per 6^{o}-square Zone. The numbers appearing in the corners of some Zones represent the actual number of reports for that Quadrat, i.e. that one-fourth of a Zone. Note that Blocks A and M are less than 6^{o} square as a result of the map being trimmed to emphasize the lower 48 states.

Figure 3A.

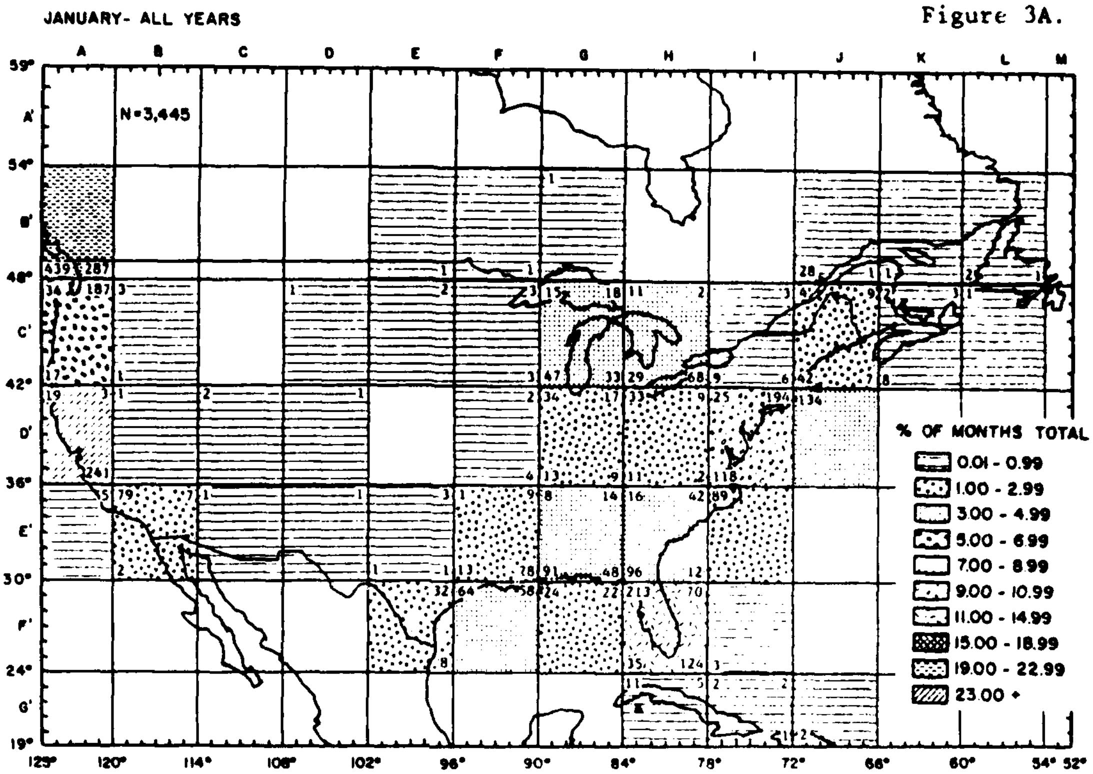
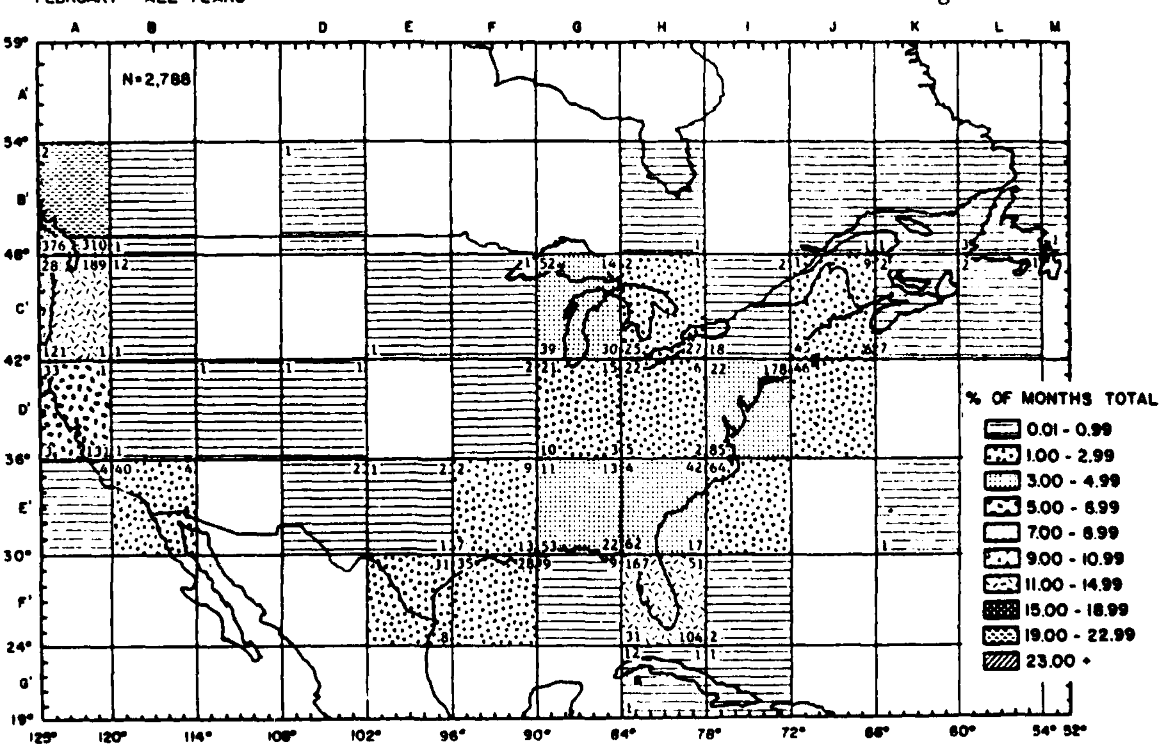
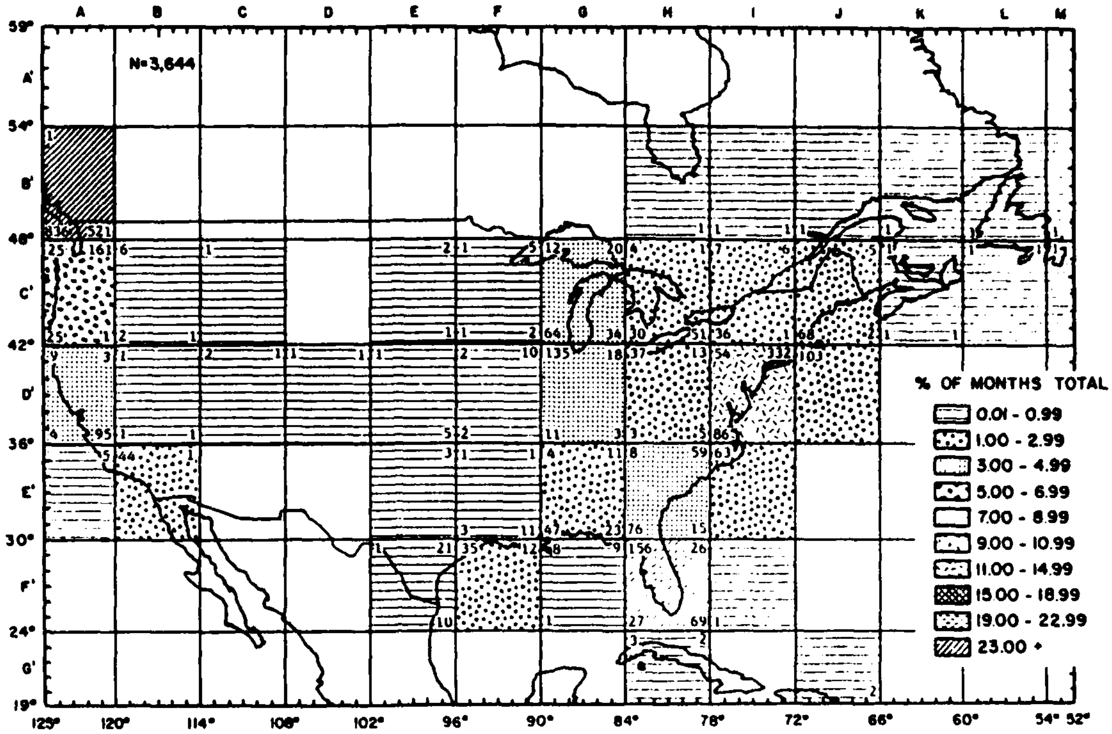


Figure 3B.



MARCH- ALL YEARS

Figure 3C.



APRIL- ALL YEARS

Figure 3D.

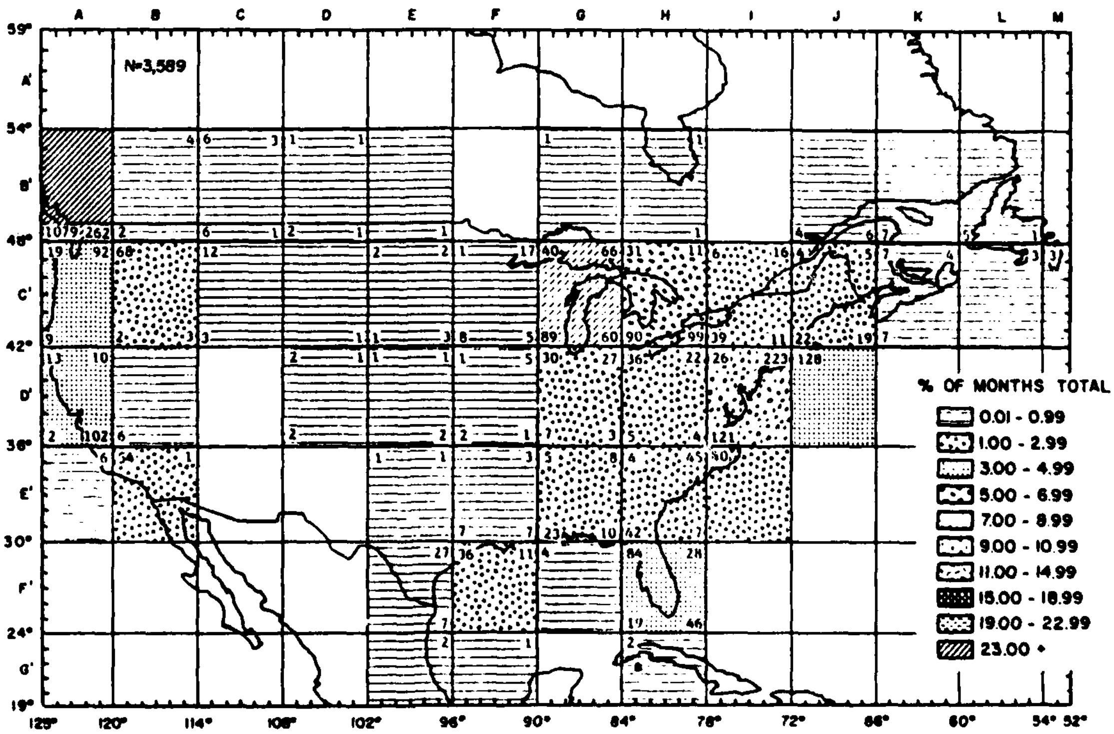


Figure 3E.

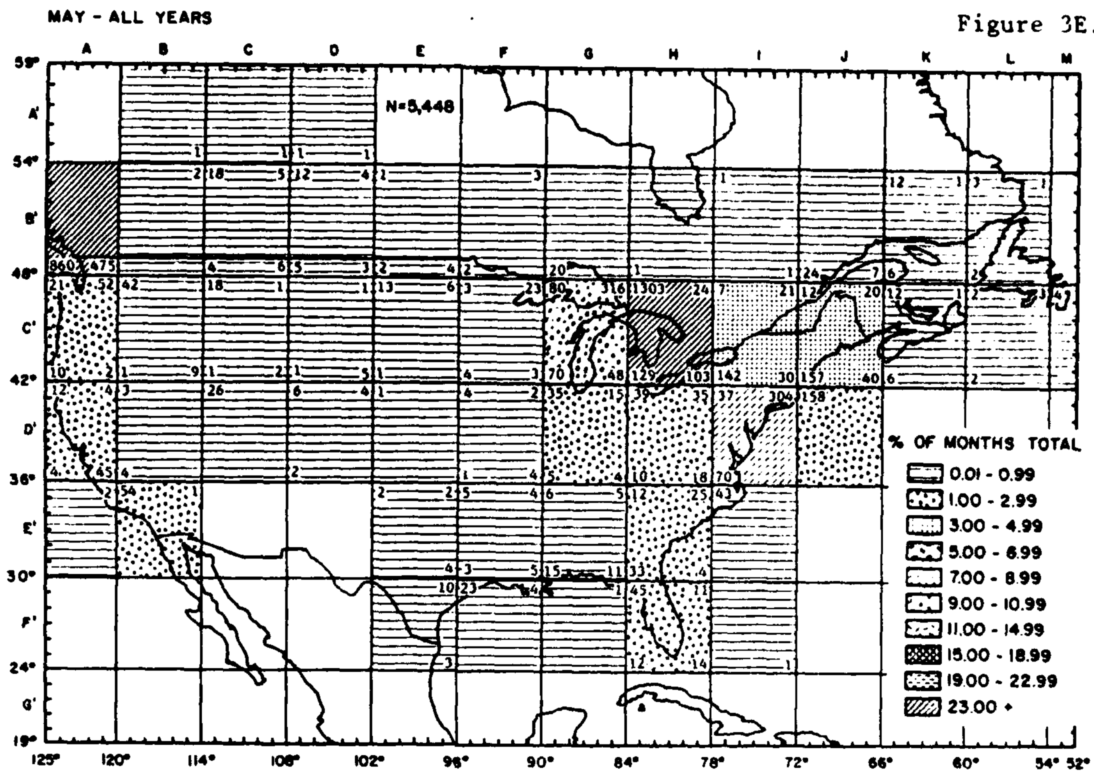


Figure 3F.

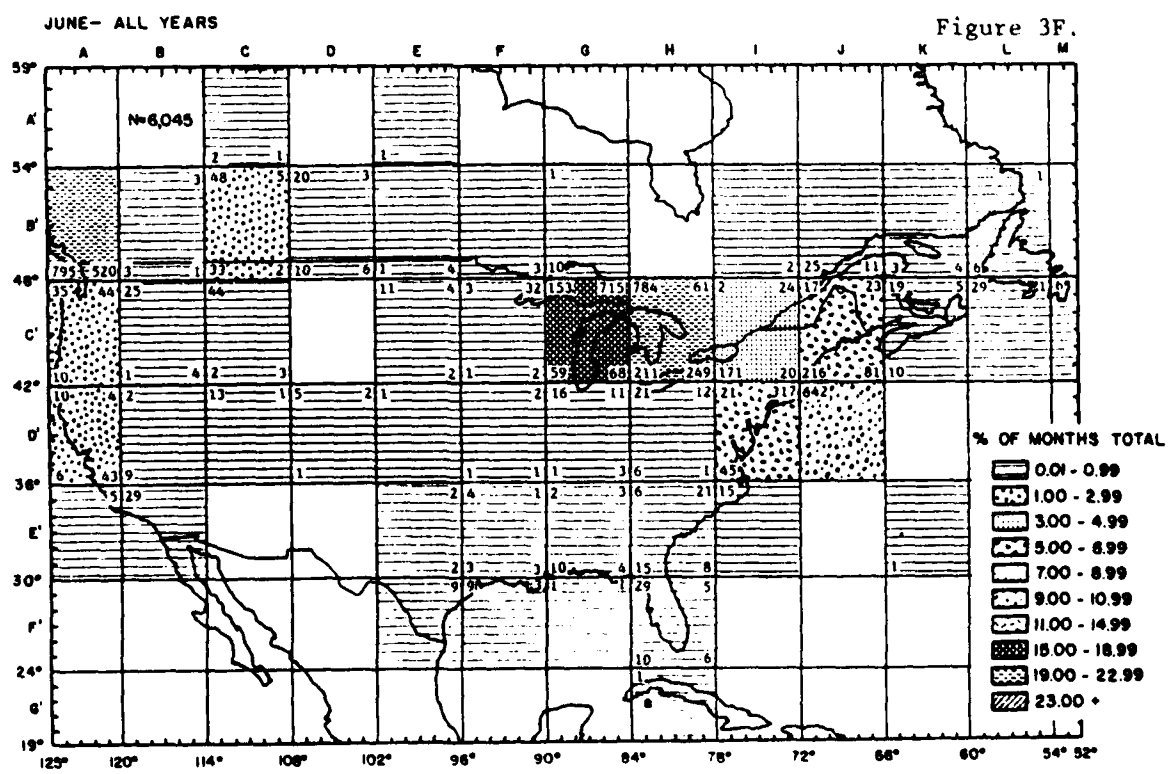


Figure 3G.

JULY-ALL YEARS

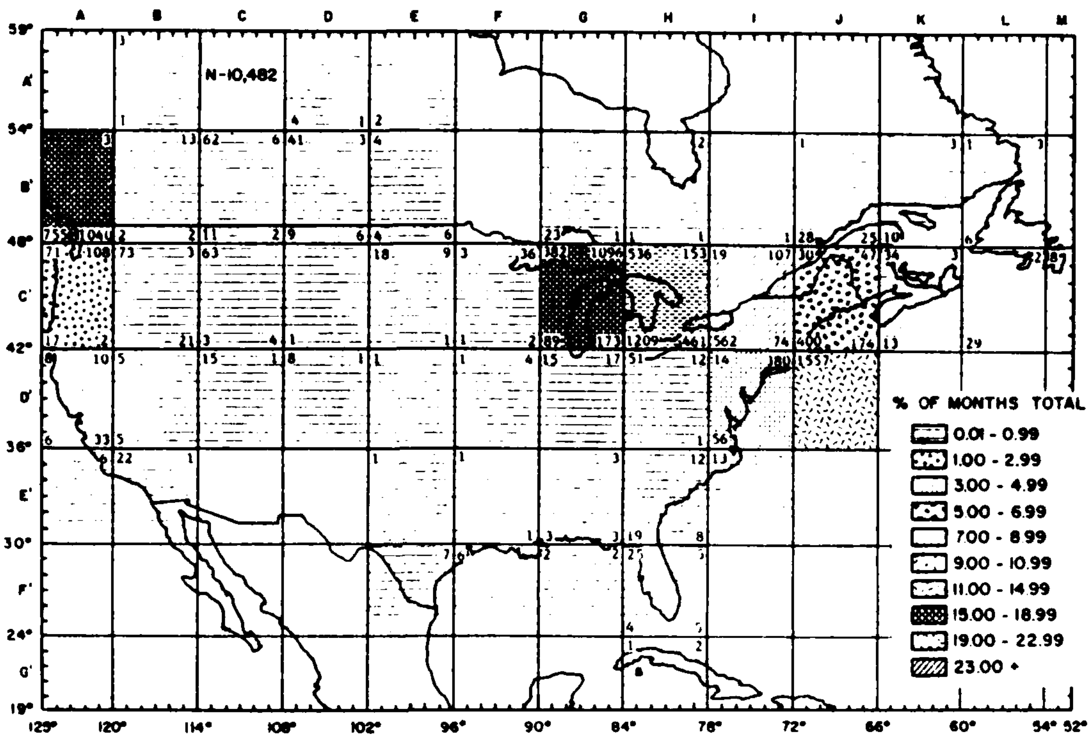
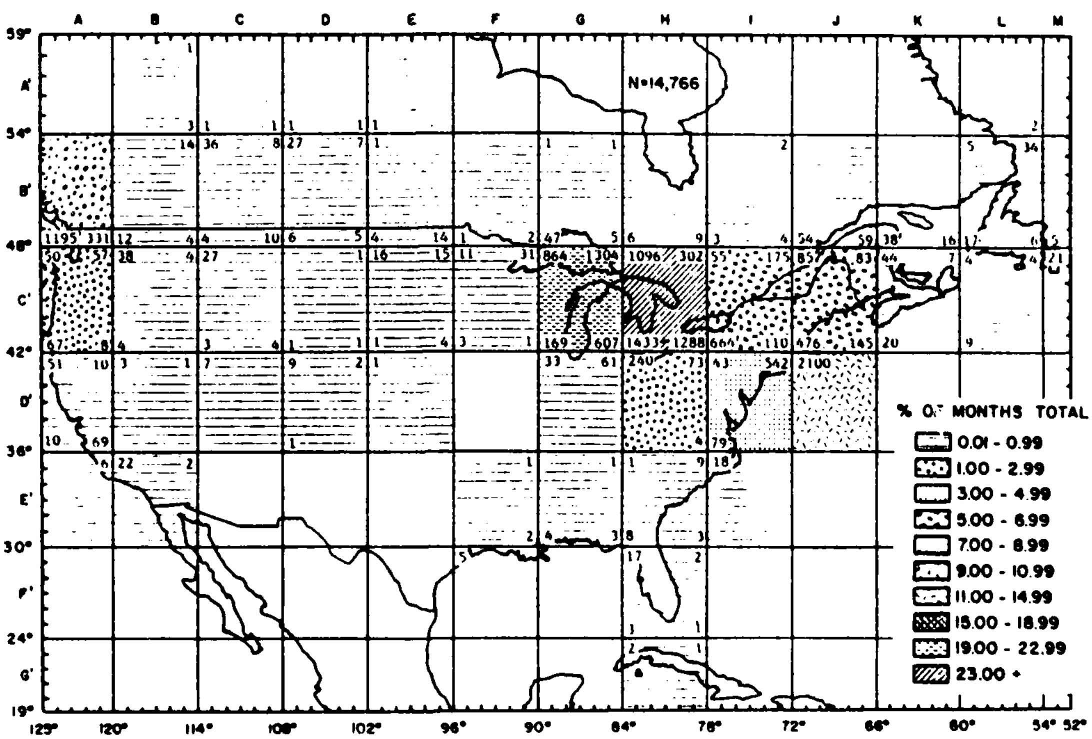


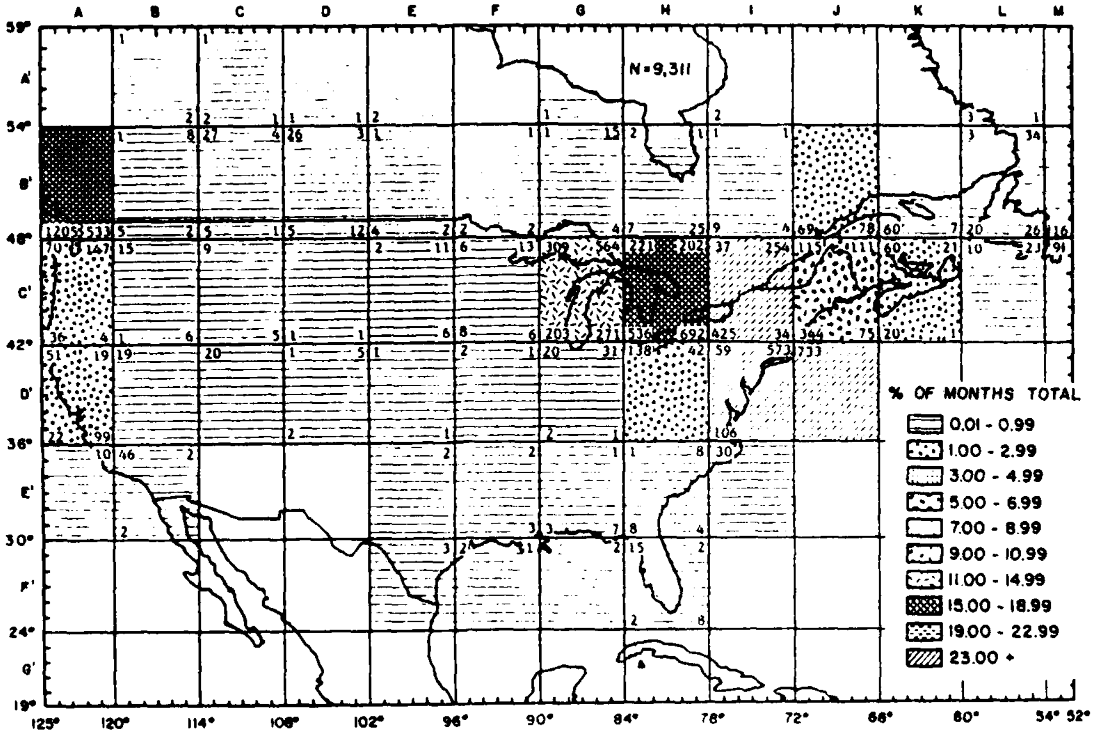
Figure 3H.

AUGUST-ALL YEARS



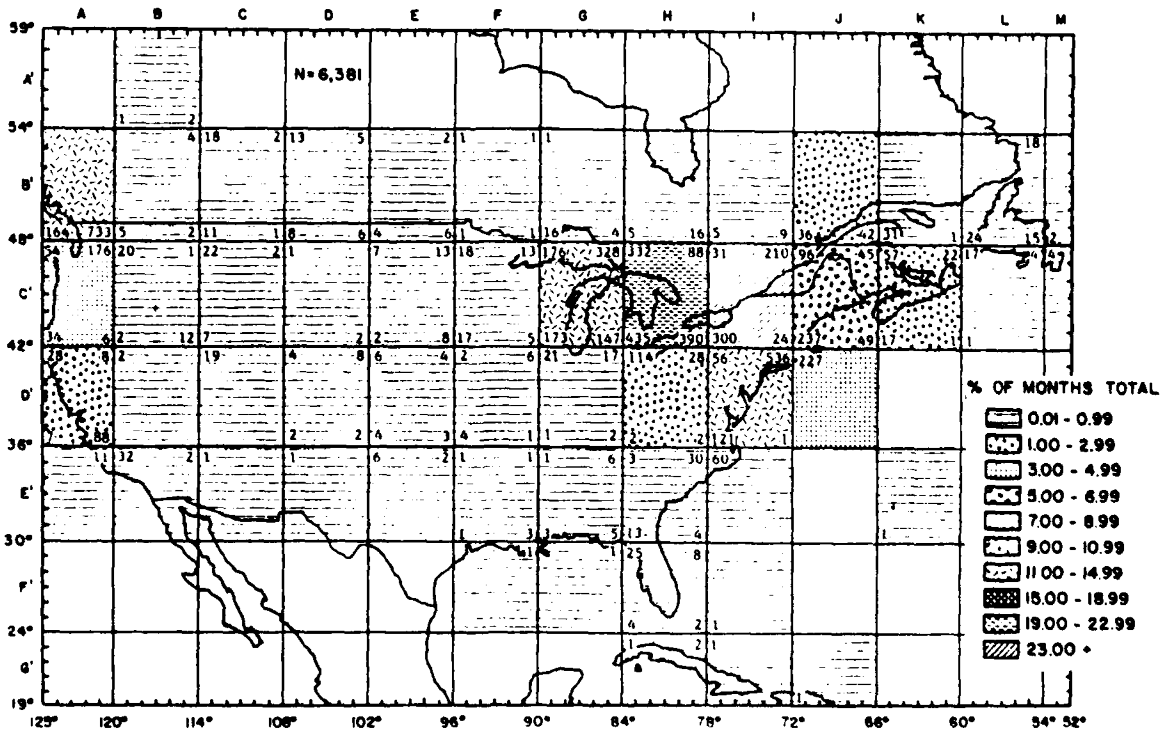
SEPTEMBER - ALL YEARS

Figure 3I.



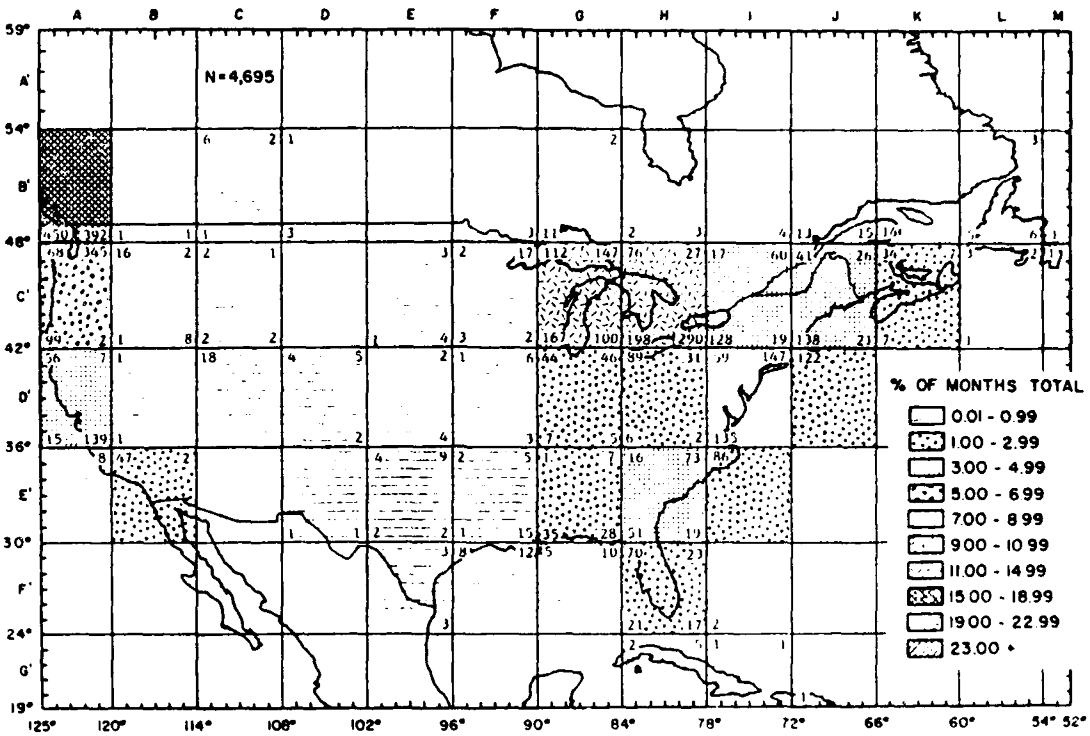
OCTOBER - ALL YEARS

Figure 3J.



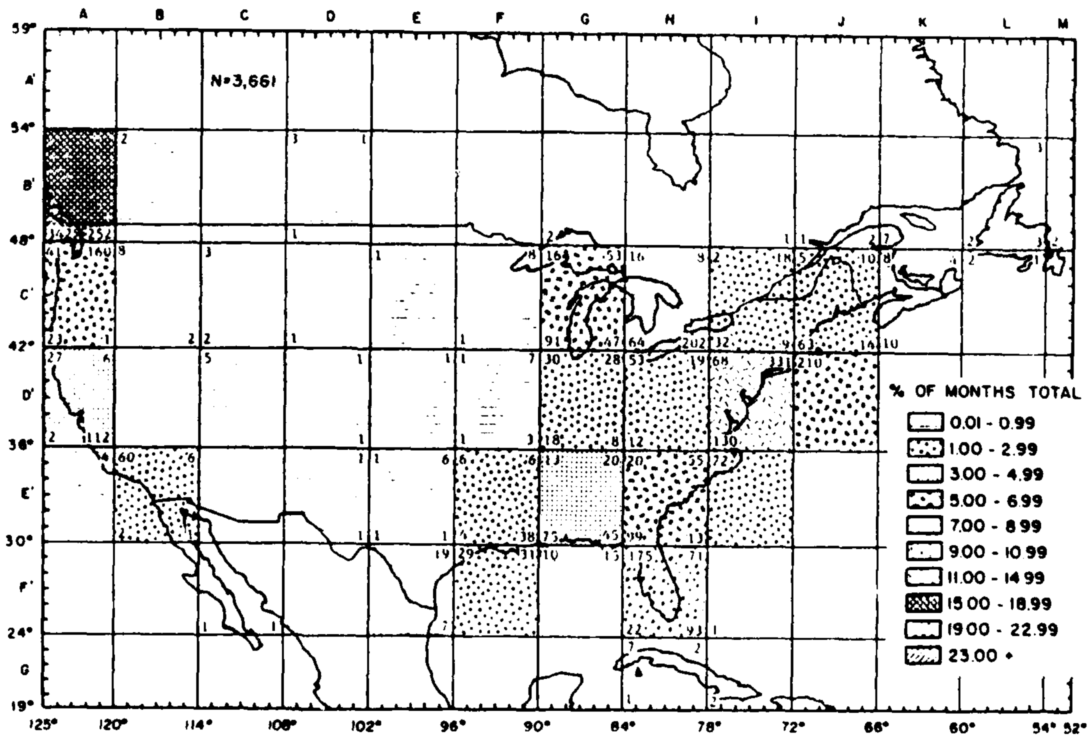
NOVEMBER- ALL YEARS

Figure 3K.



DECEMBER - ALL YEARS

Figure 3L.



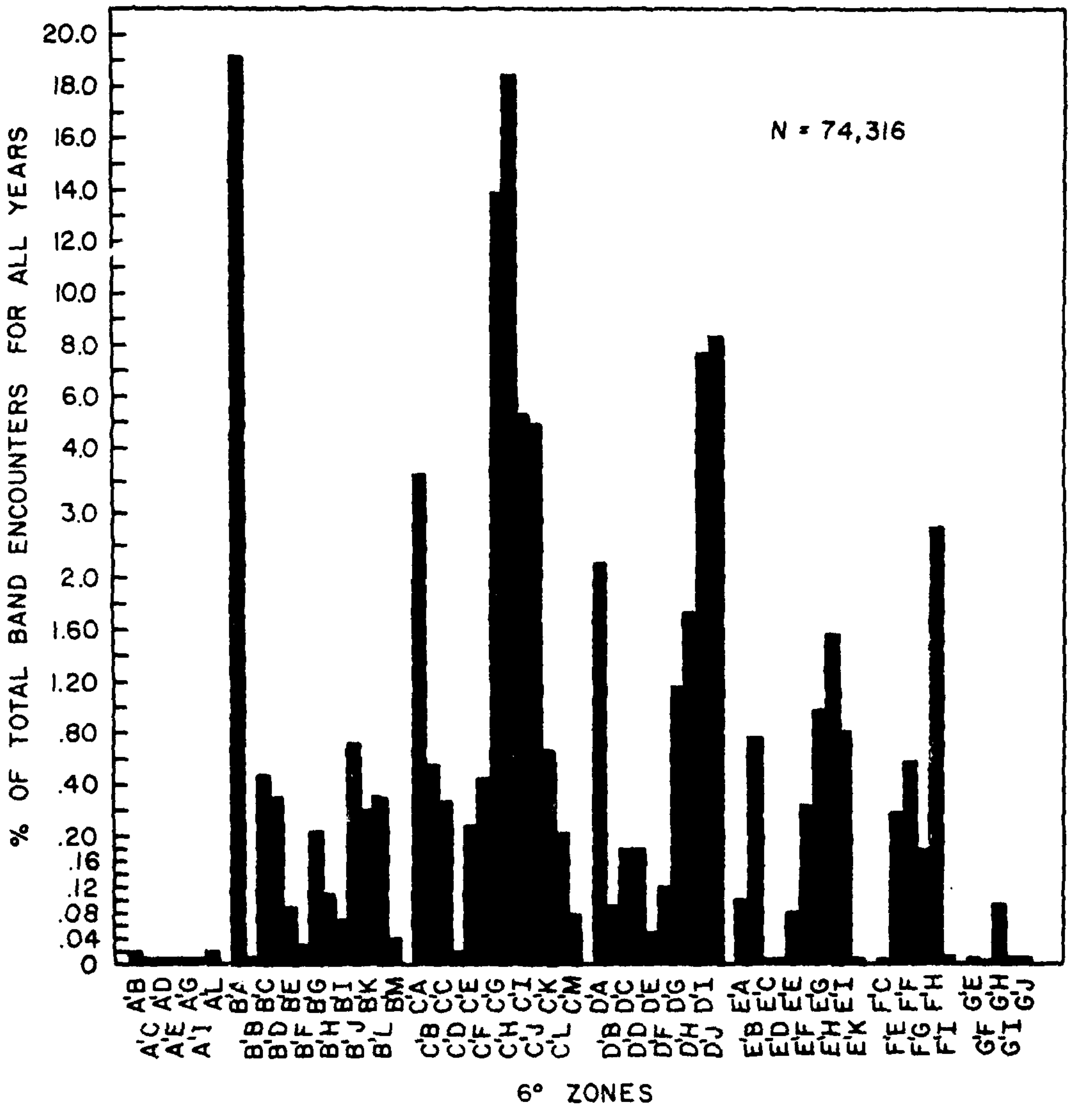


Figure 4. The proportion of all band recoveries reported from each 6° Zone.

Figure 3K.

NOVEMBER- ALL YEARS

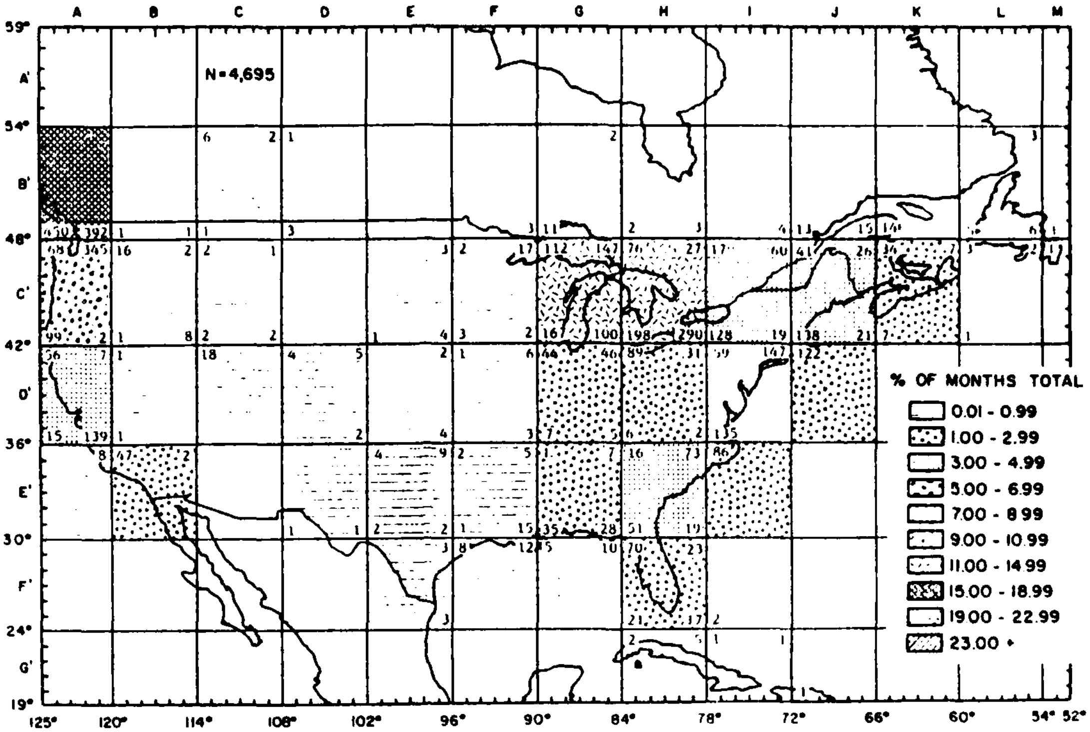


Figure 3L.

DECEMBER - ALL YEARS

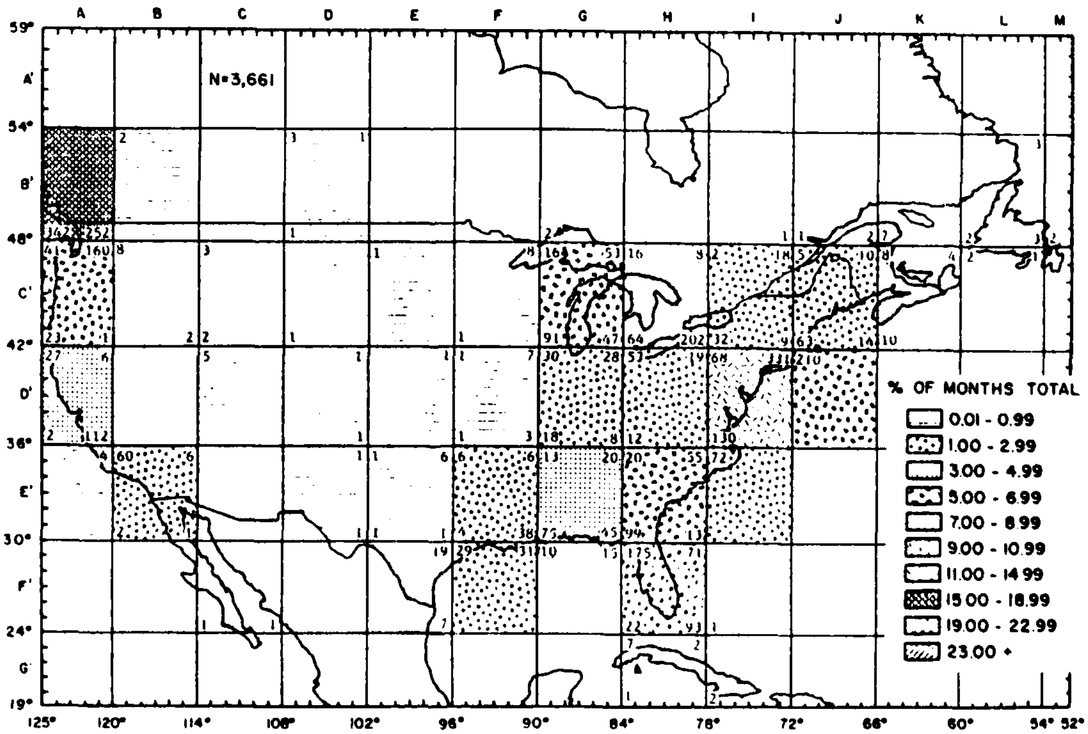


Figure 5A-D. Percent of each quarter's National Wildlife Refuge data reported in each 6° Zone.

Figure 5A.

1ST PERIOD: JANUARY-MARCH, 1975. USFWS REFUGE DATA

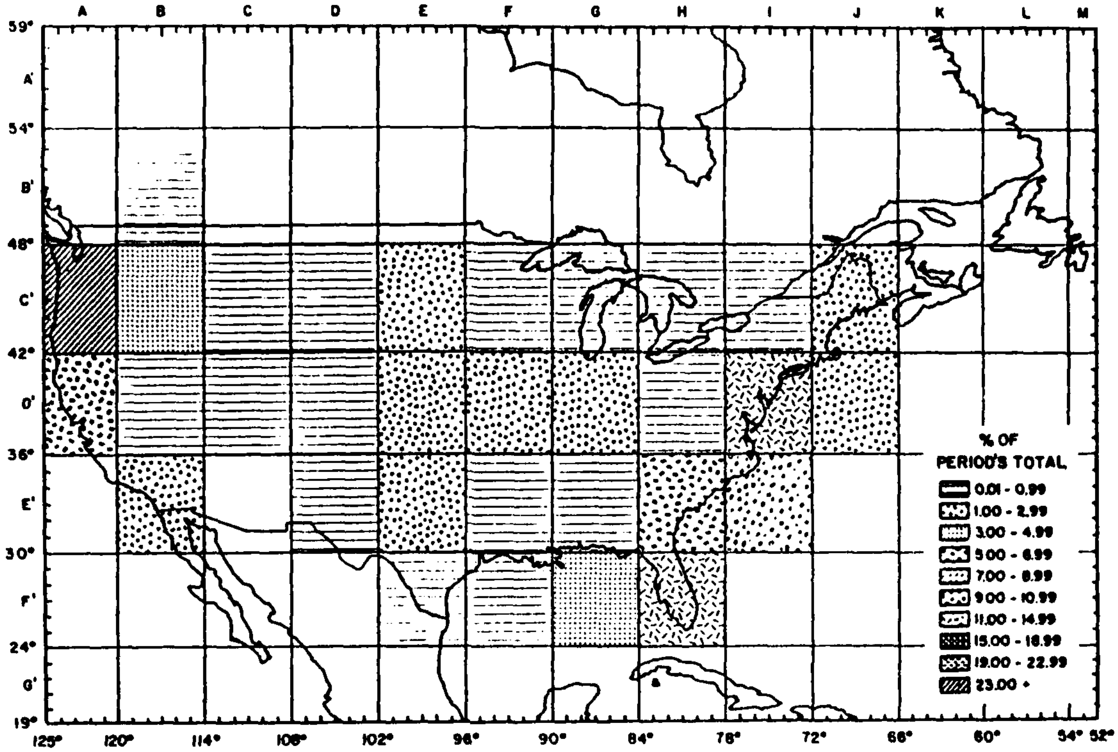


Figure 5B.

2 ND PERIOD: APRIL-JUNE, 1975. USFWS REFUGE DATA

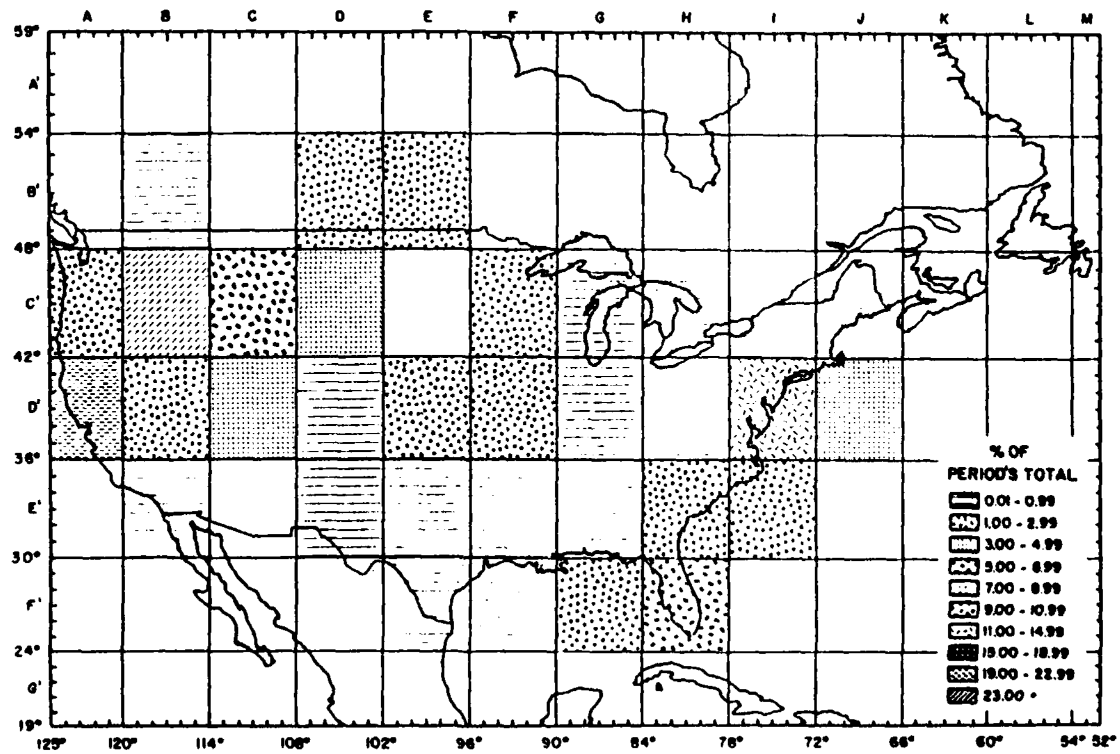


Figure 5C.

3RD PERIOD: JULY-SEPTEMBER, 1975.

USFWS REFUGE DATA

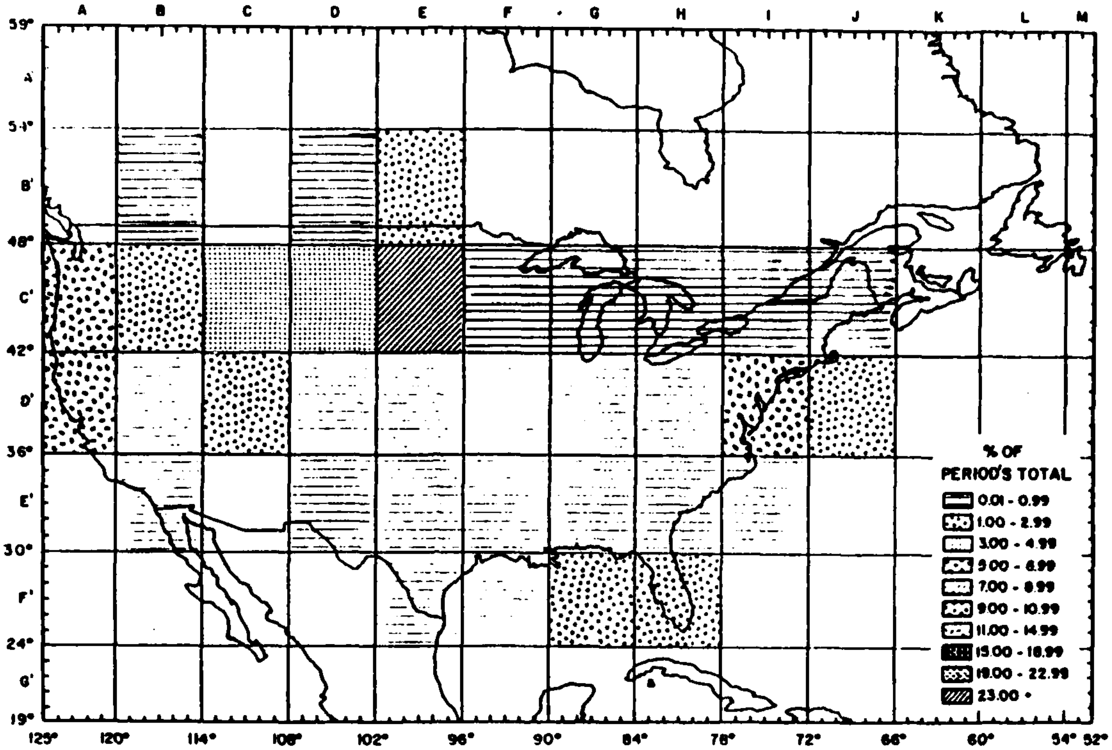
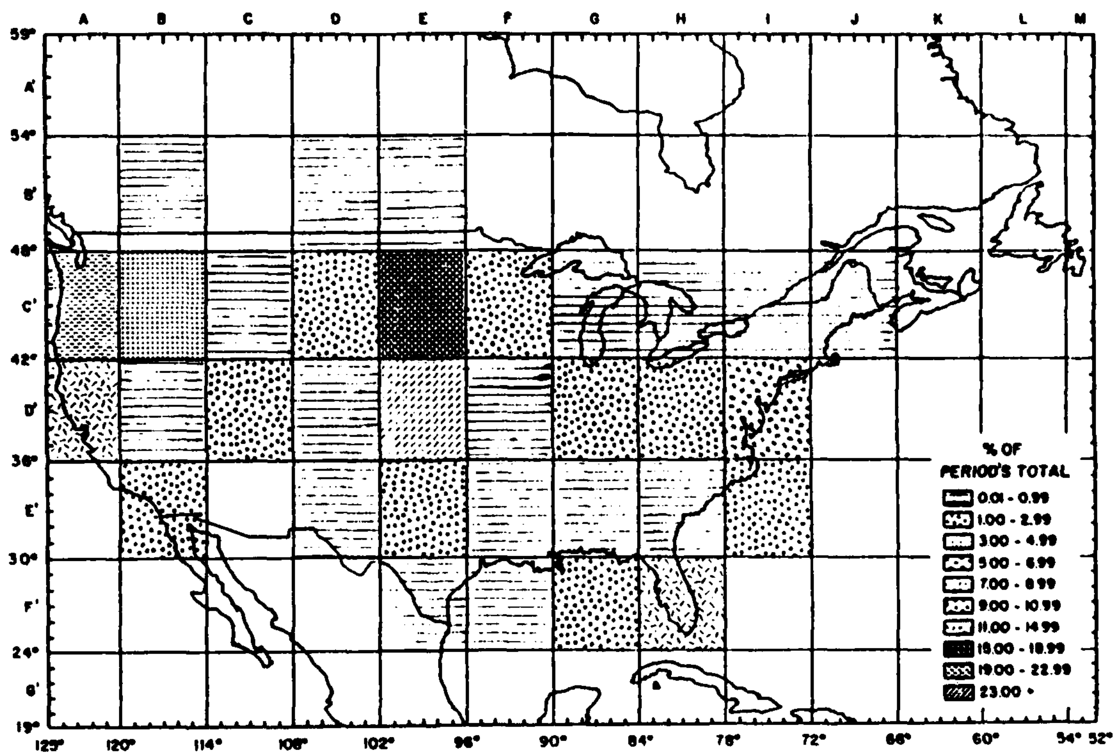


Figure 5D.

4TH PERIOD: OCTOBER-DECEMBER, 1975.

USFWS REFUGE DATA



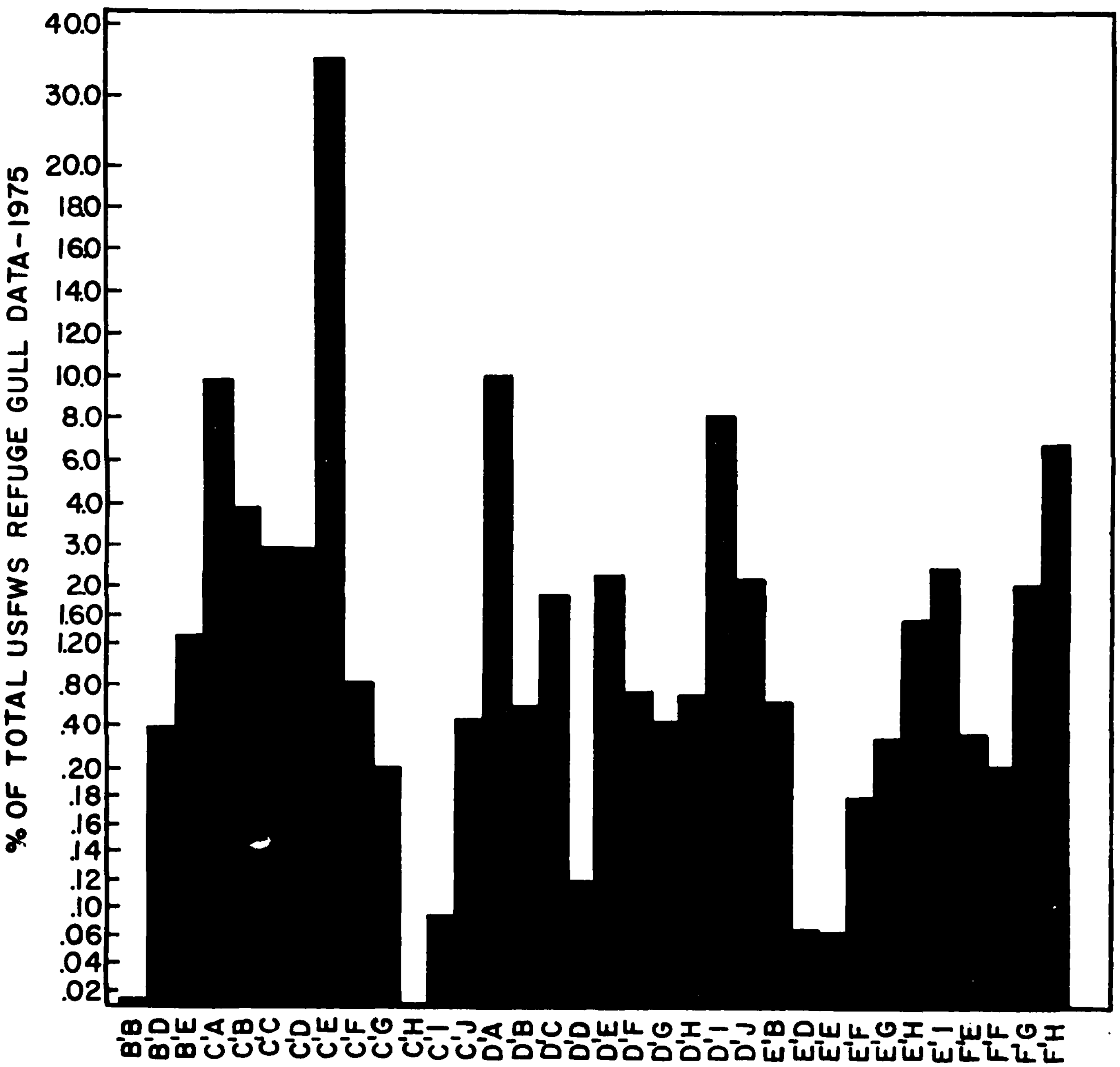


Figure 6. The proportion of all gulls reported at National Wildlife Refuges in 1975 plotted according to geographic Zones.

Figure 7B'B through F'H. This series of graphs for National Wildlife Refuge data (1975) indicate 1) the proportion of all gulls reported that occurred within a particular Zone during each of the 4-periods of the year (solid line), and 2) the proportion of each Zone's total that occurred within each of the 4 Quarters of each Zone (histogram). This latter procedure provides an indication of how gulls are distributed within each Zone.

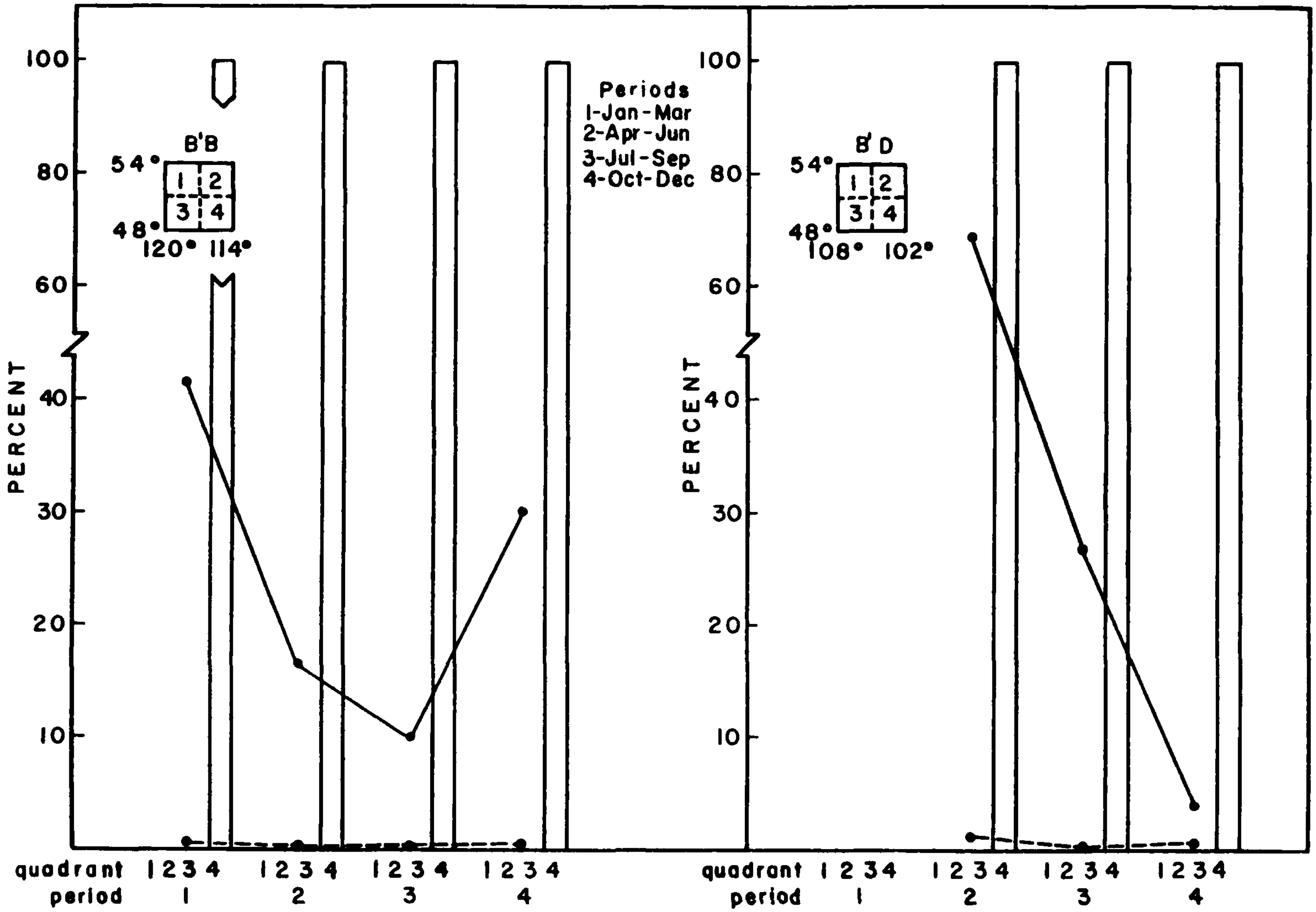


Figure 7. Zone B'B.

Figure 7. Zone B'D

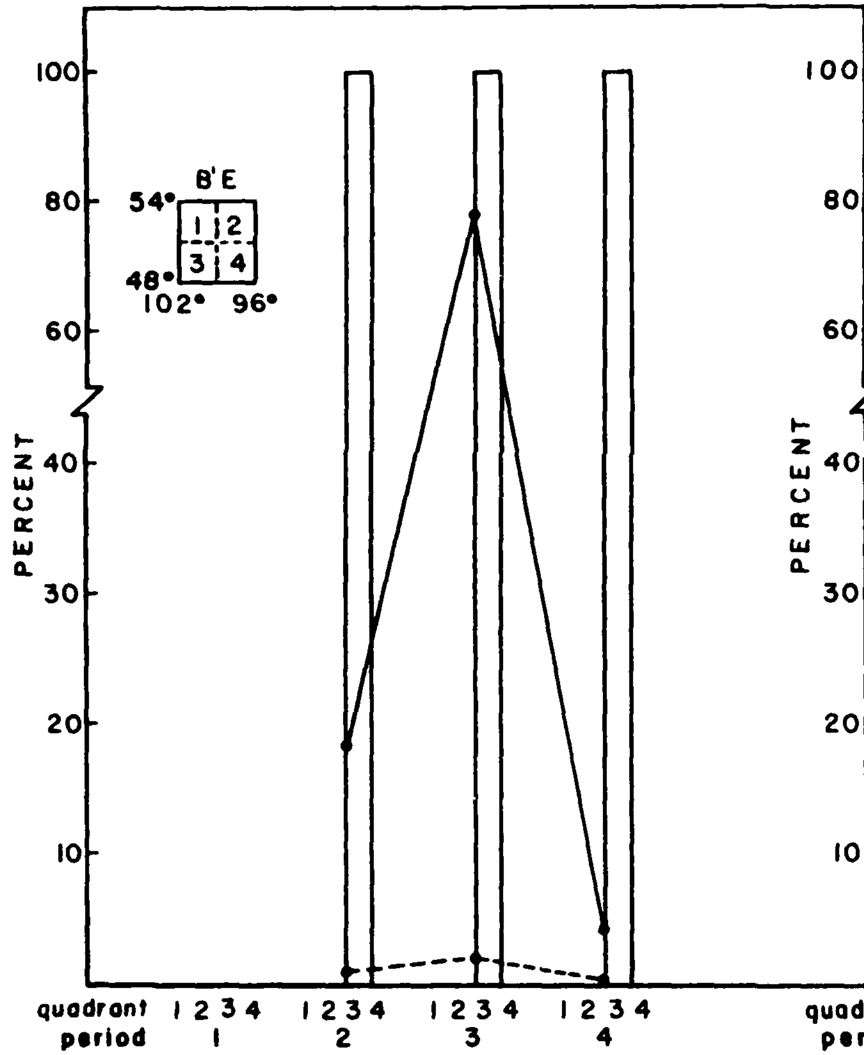


Figure 7. Zone B'E.

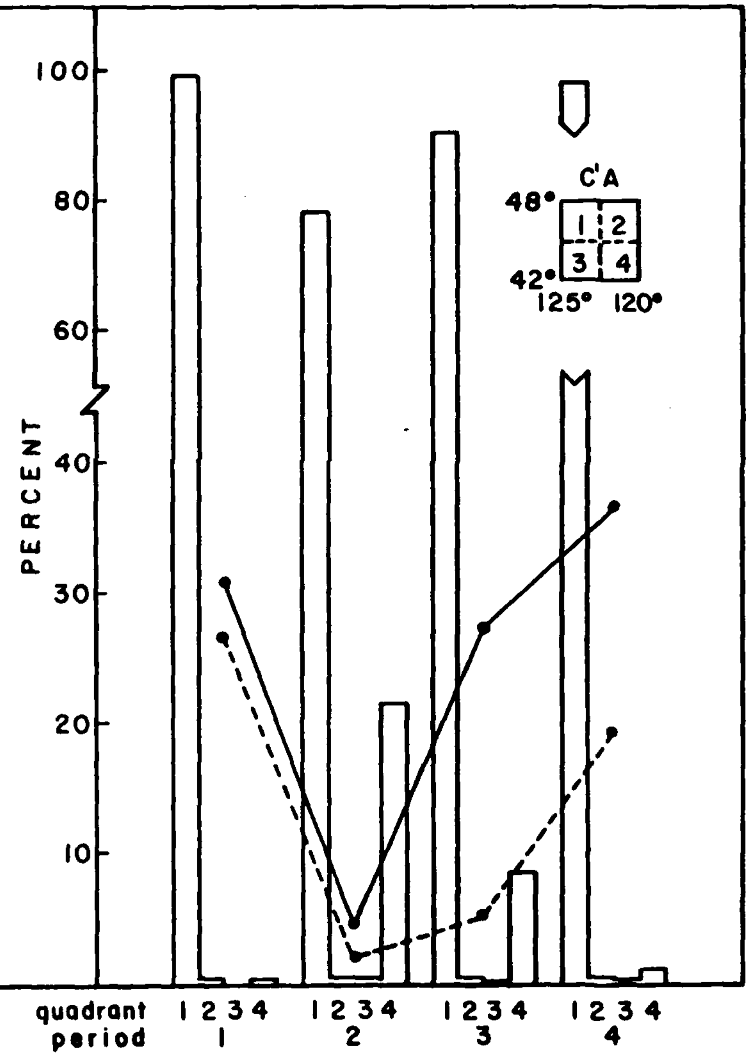


Figure 7. Zone C'A.

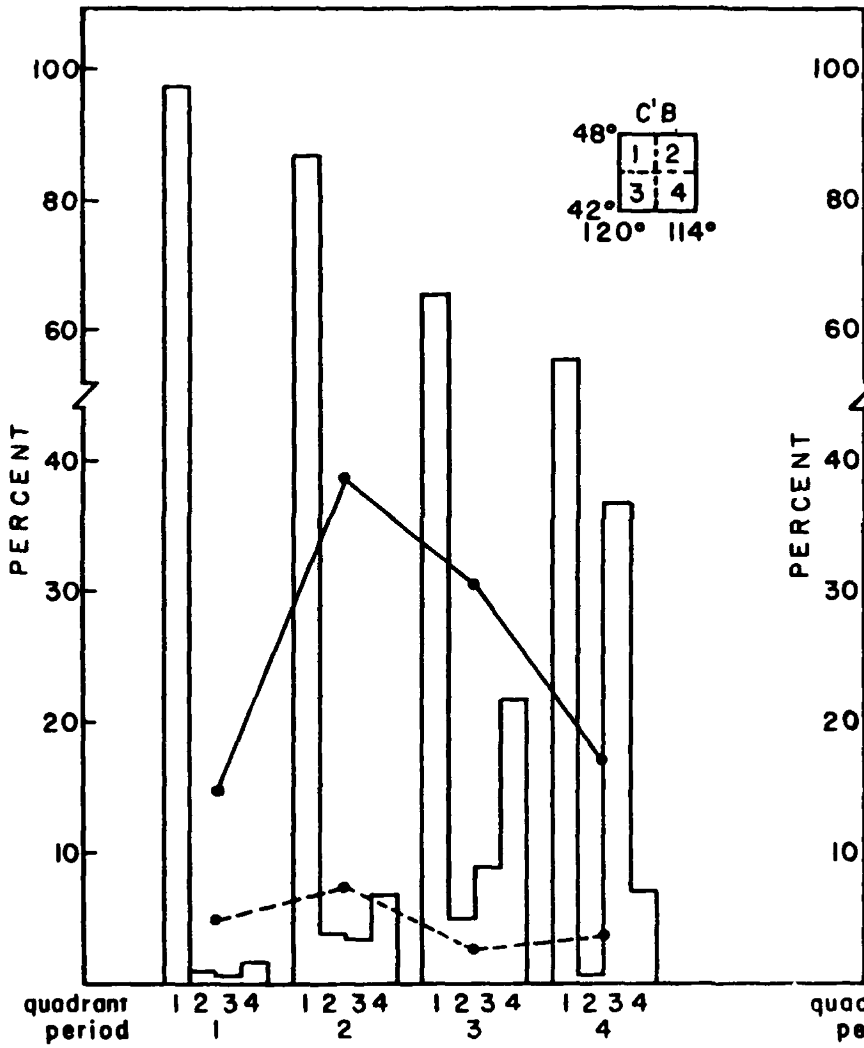


Figure 7. Zone C'B.

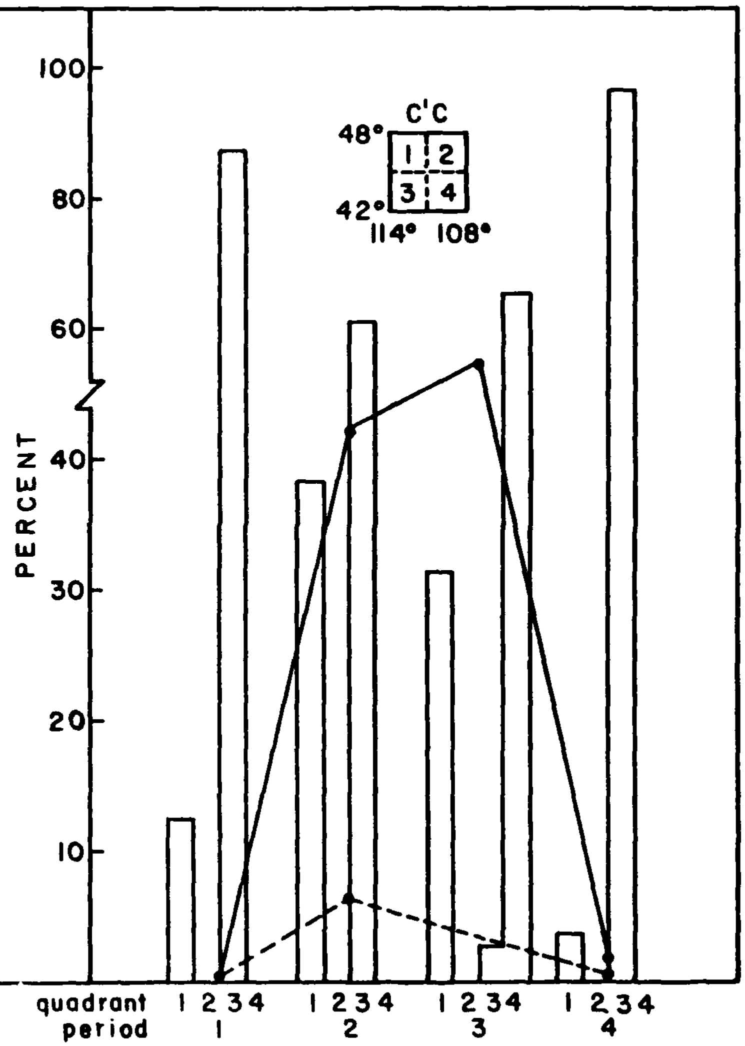


Figure 7. Zone C'C.

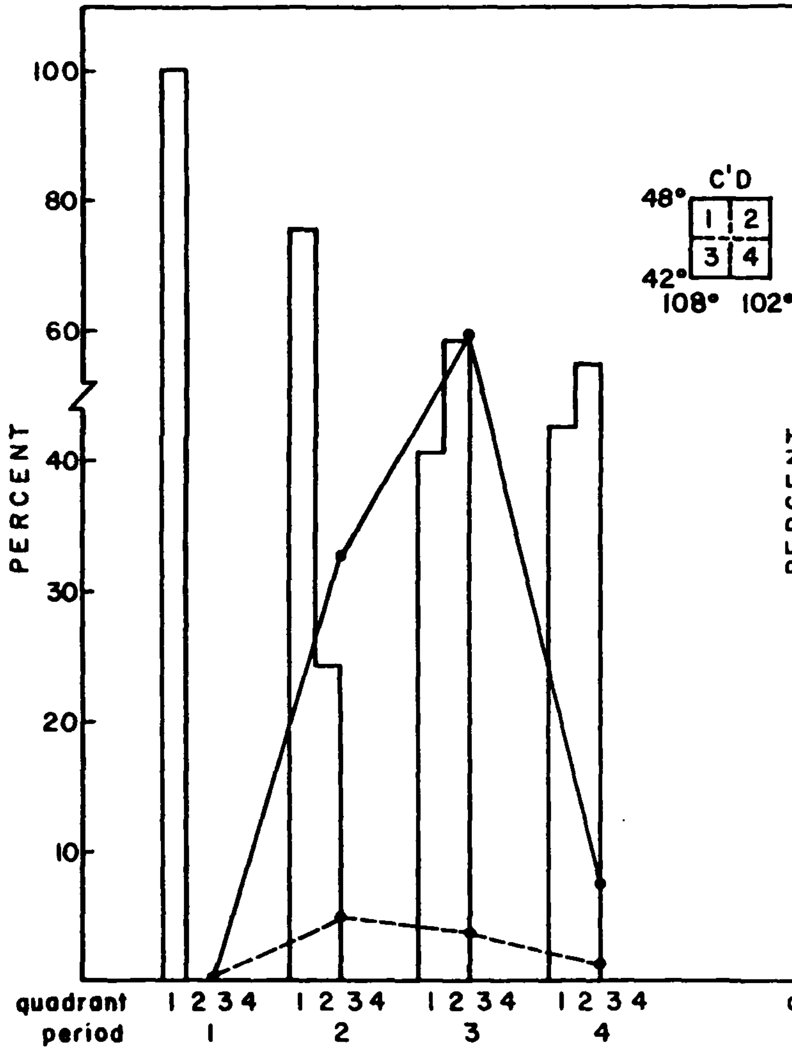


Figure 7. Zone C'D.

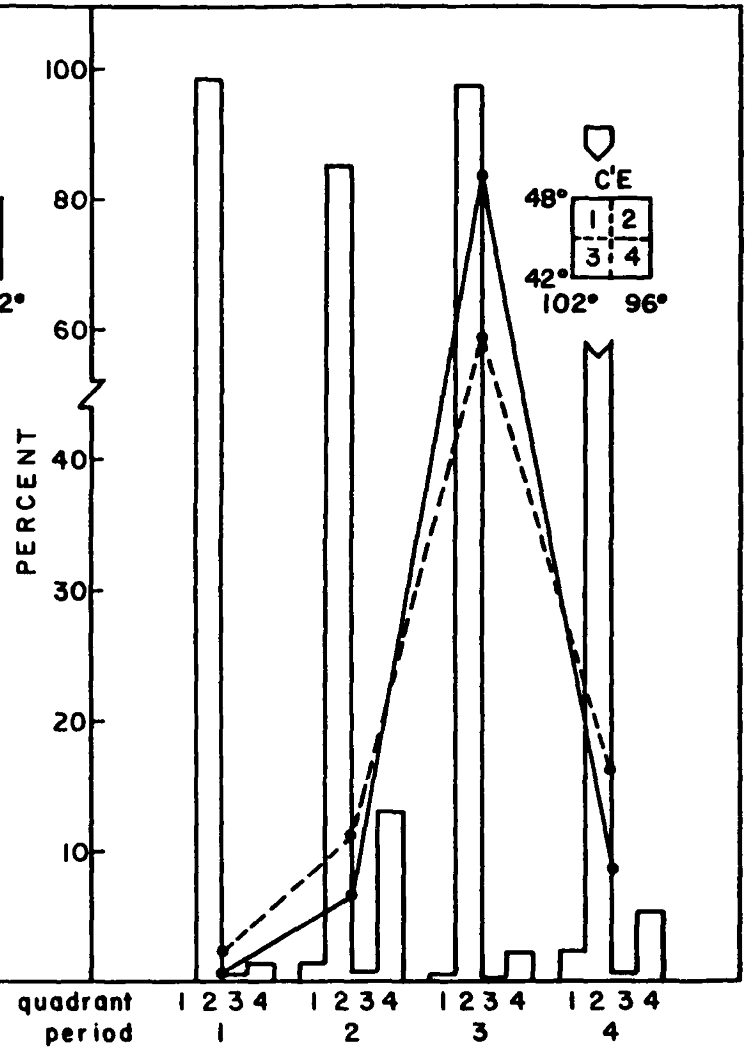


Figure 7. Zone C'E.

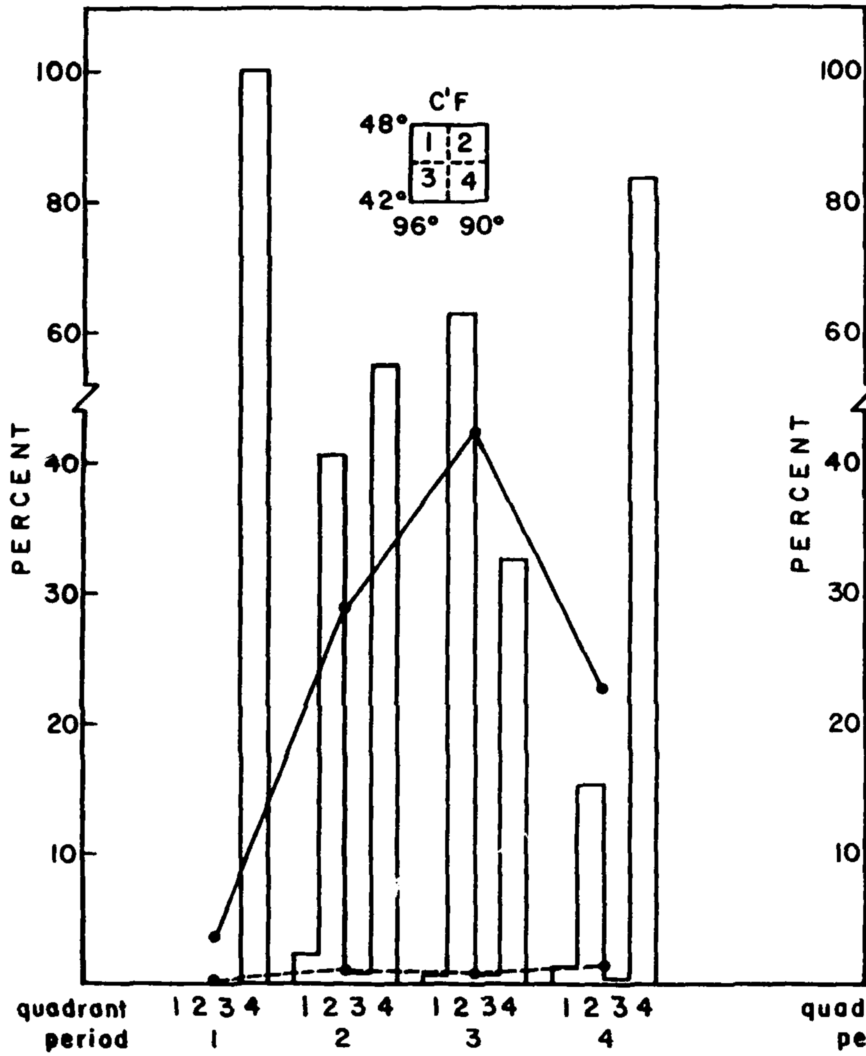


Figure 7. Zone C'F.

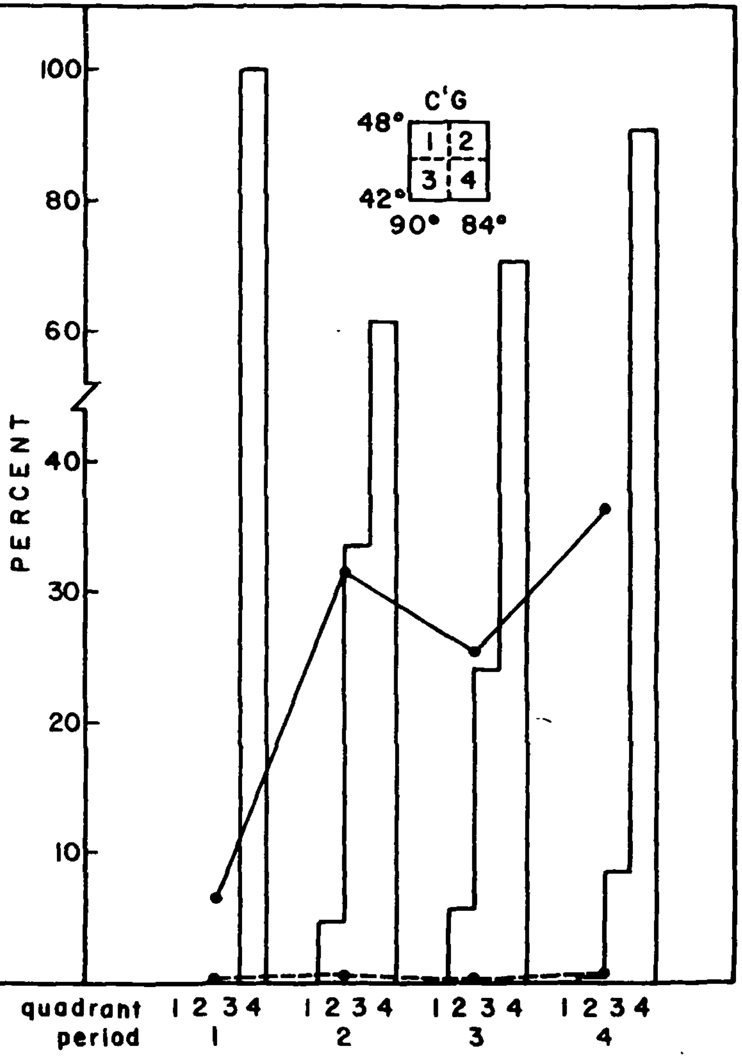


Figure 7. Zone C'G.

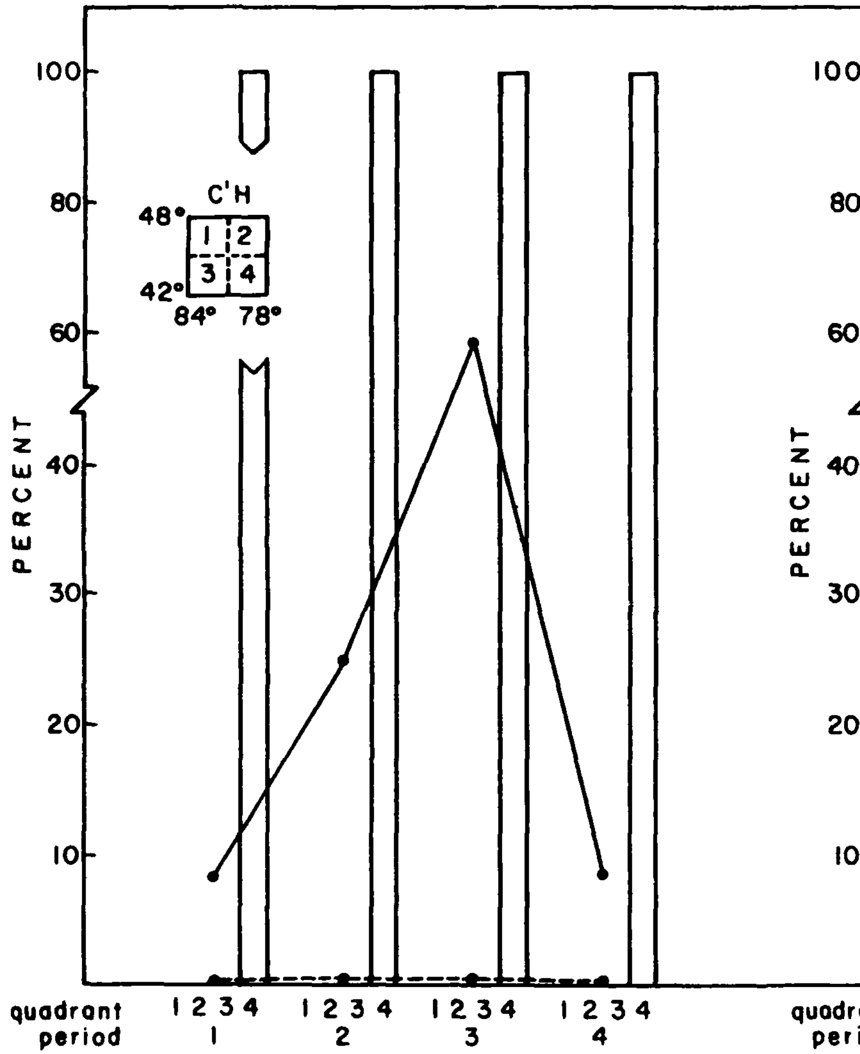


Figure 7. Zone C'H.

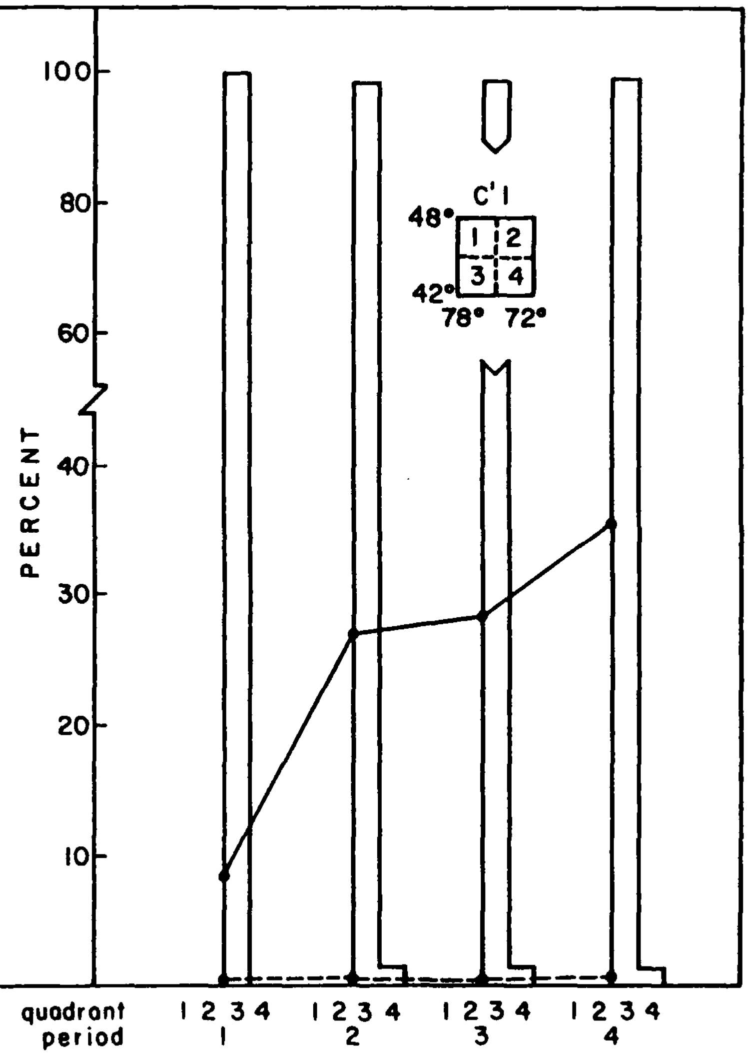


Figure 7. Zone C'I.

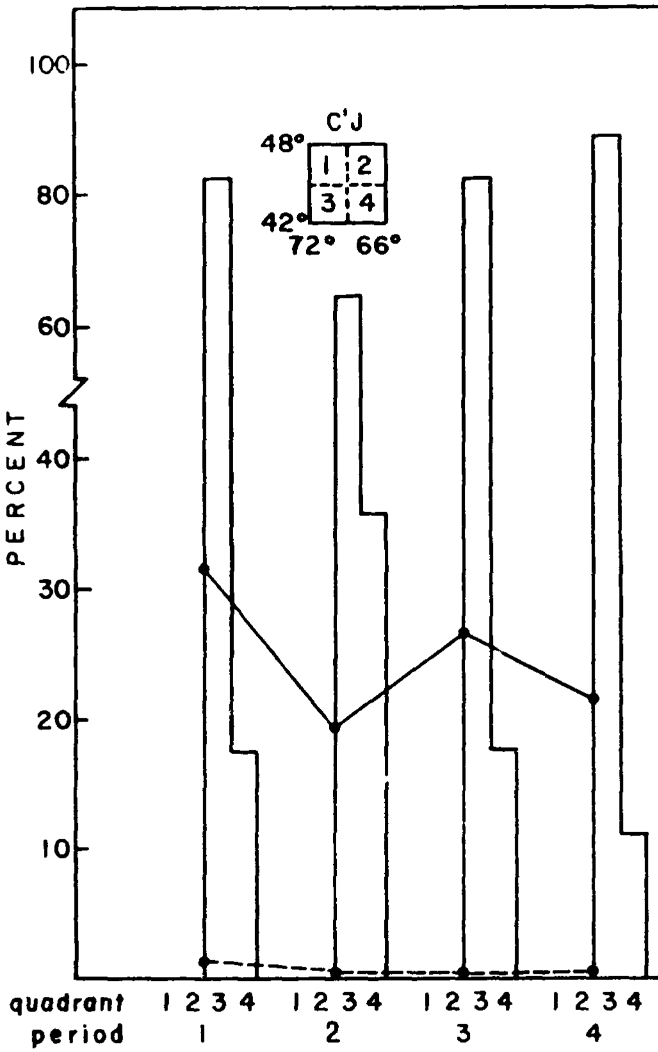


Figure 7. Zone C'J.

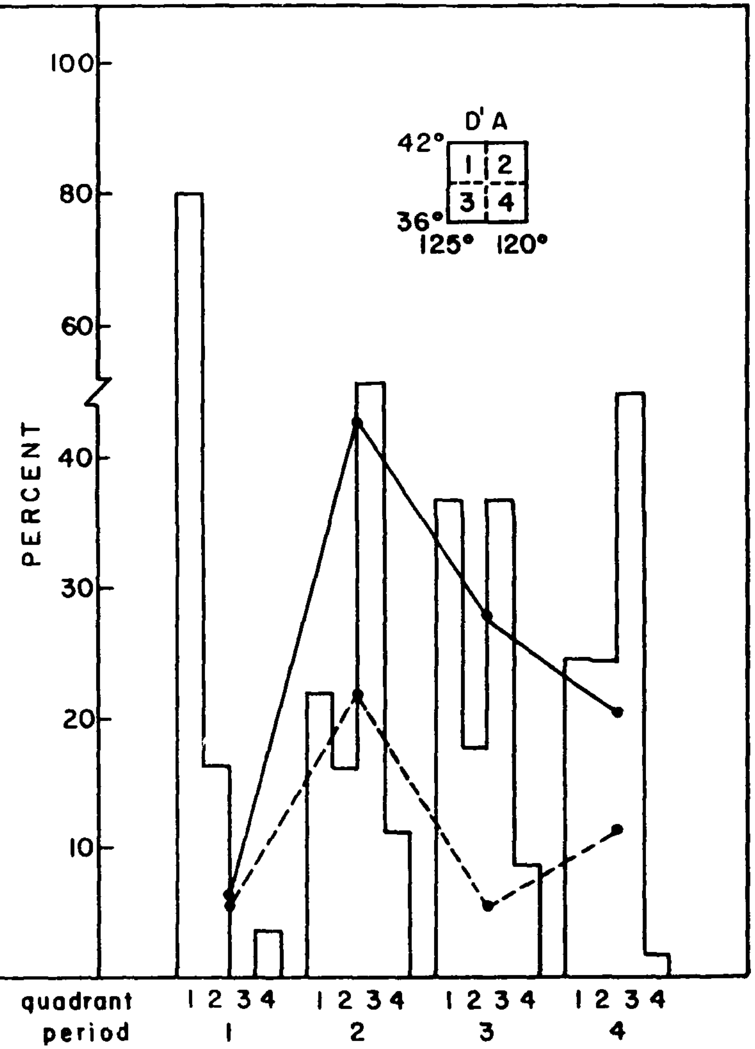


Figure 7. Zone D'A.

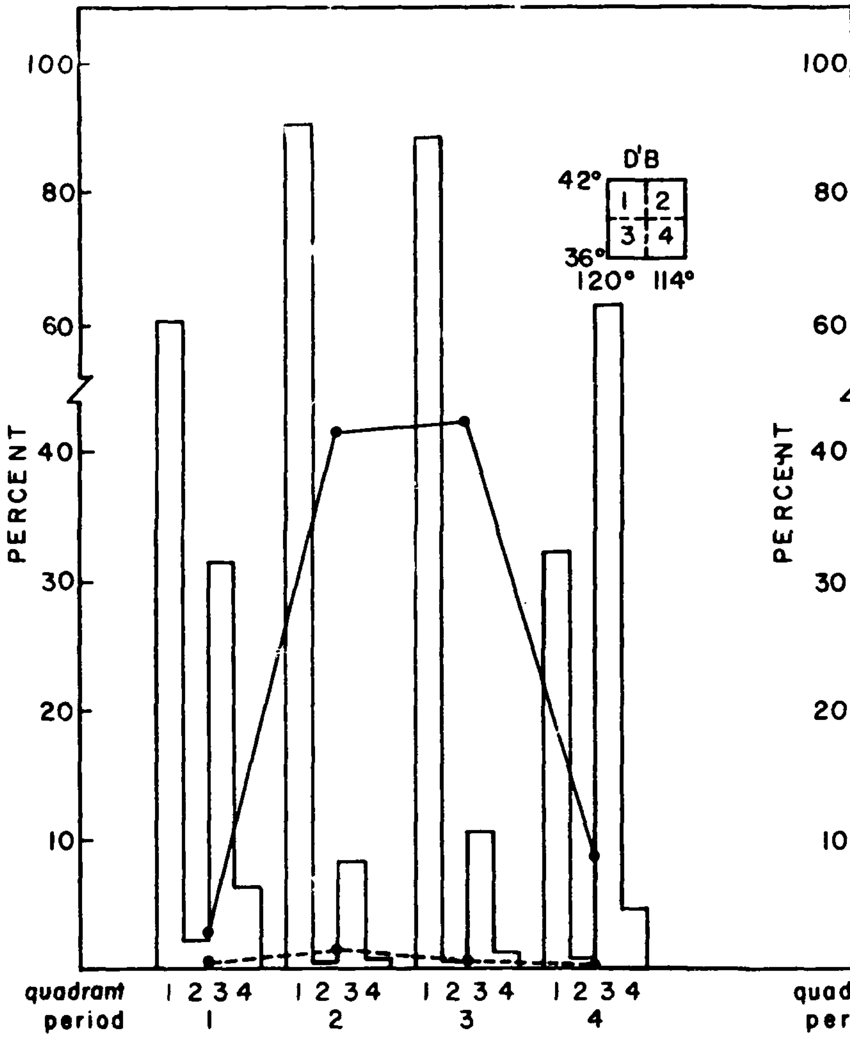


Figure 7. Zone D'B.

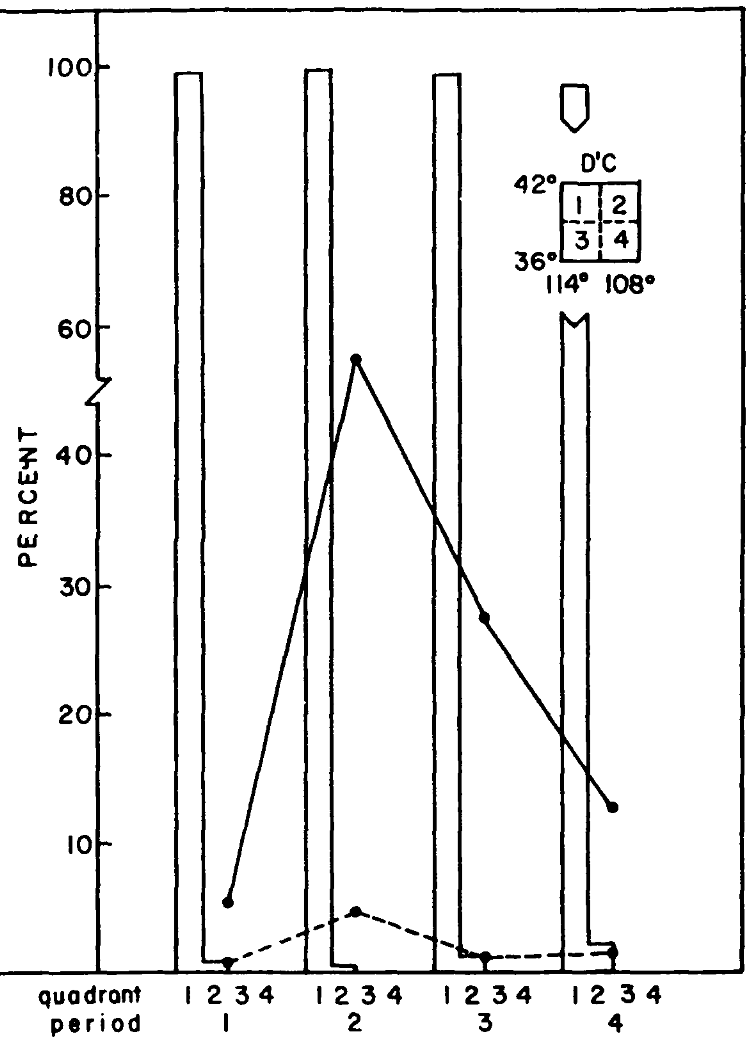


Figure 7. Zone D'C.

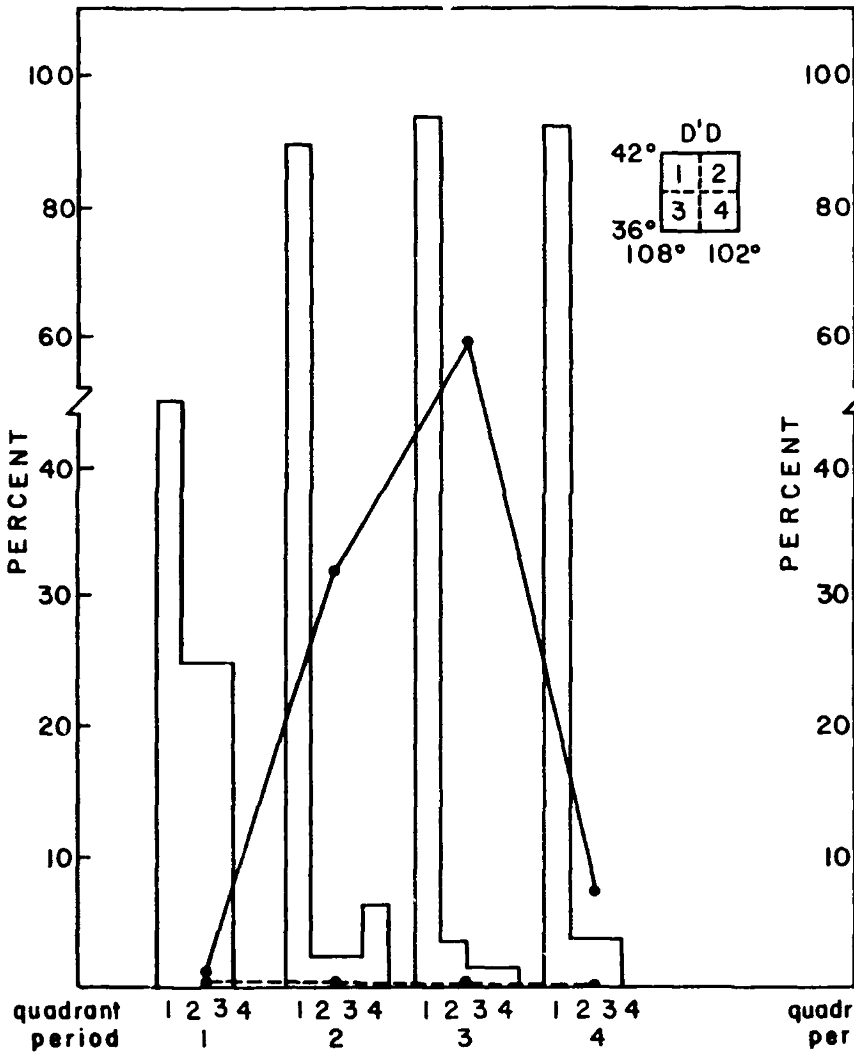


Figure 7. Zone D'D.

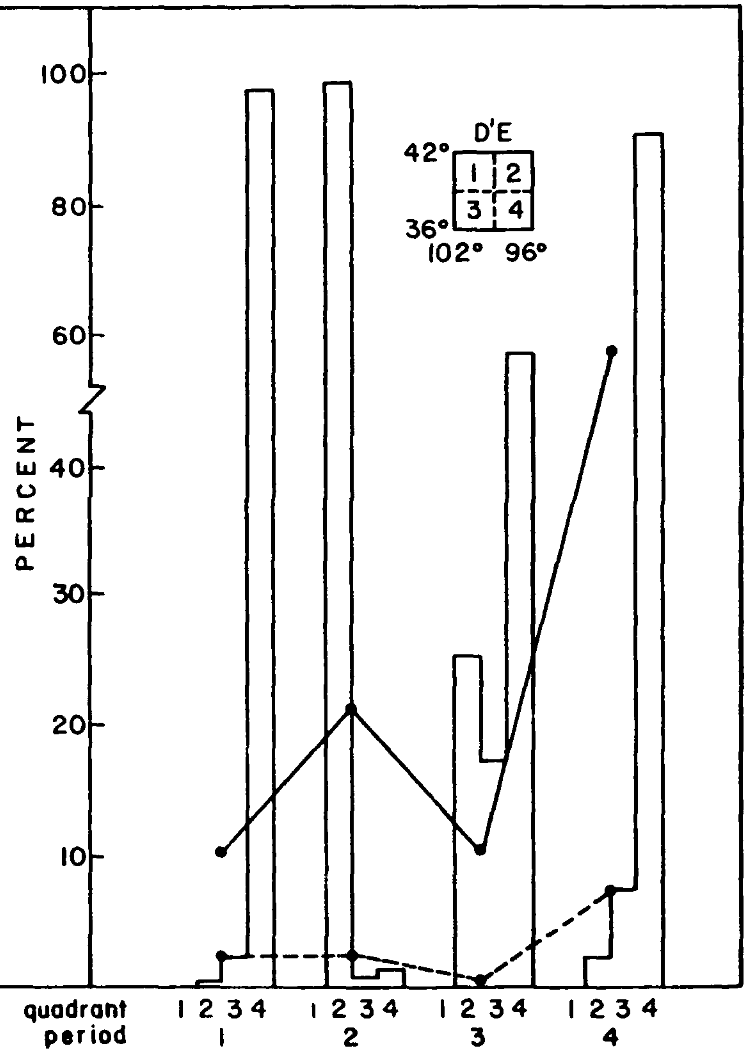


Figure 7. Zone D'E.

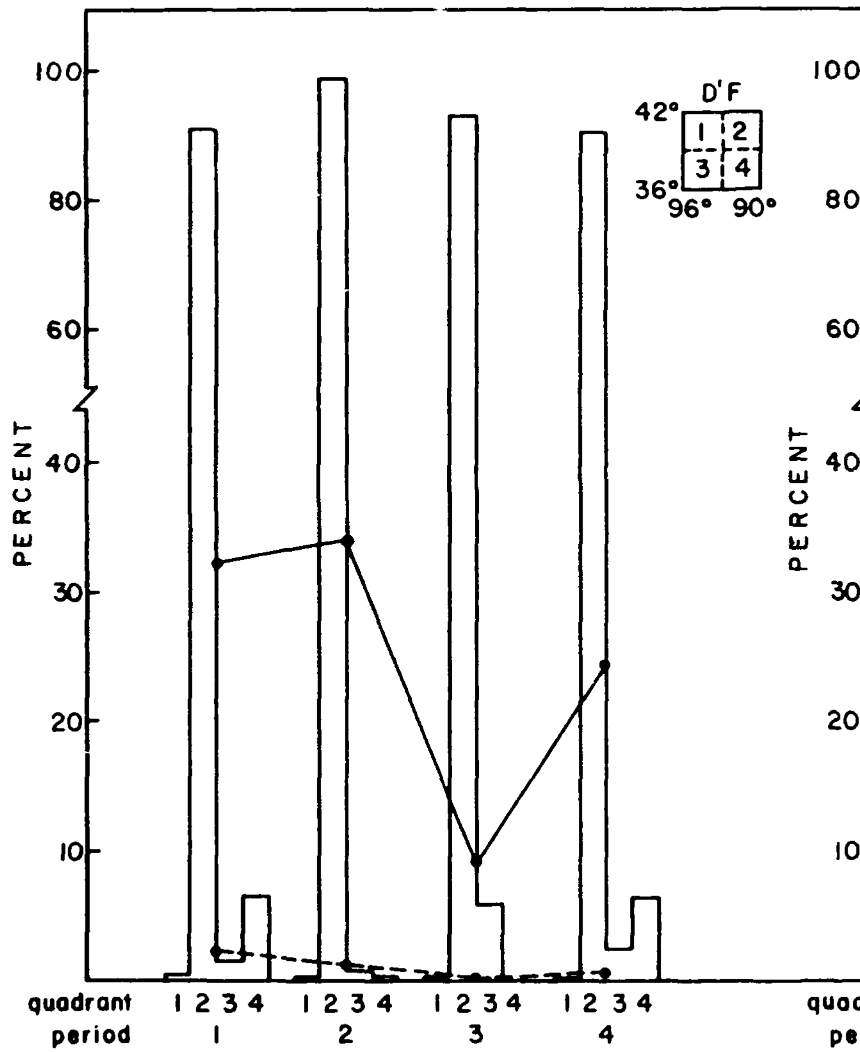


Figure 7. Zone D'F.

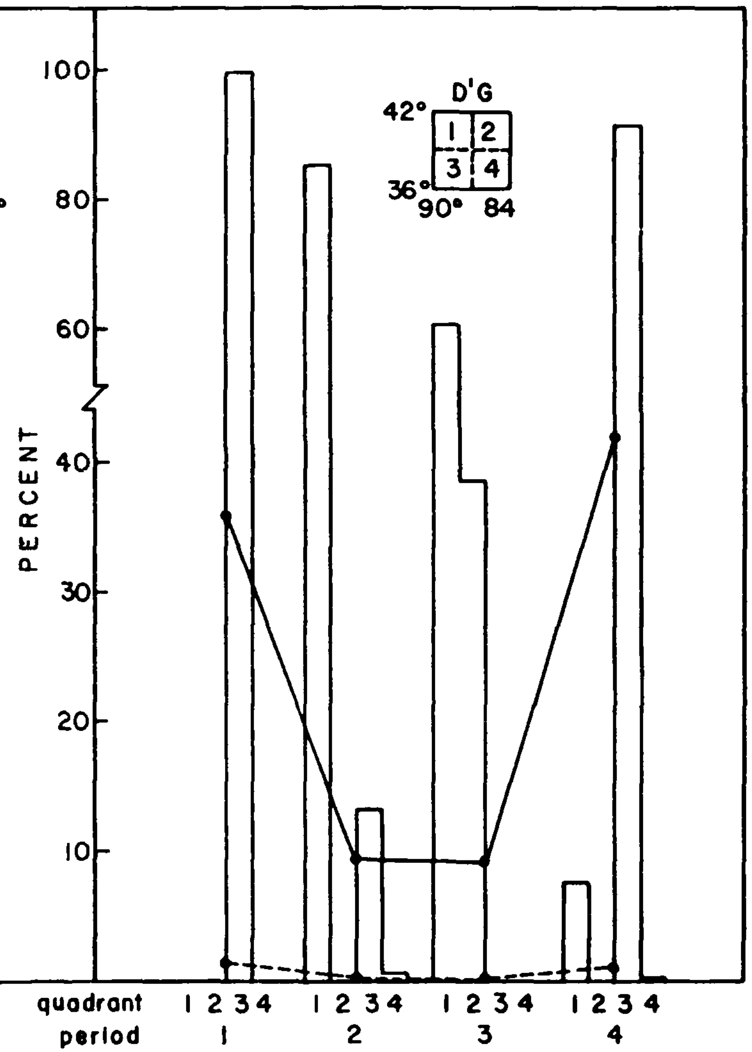


Figure 7. Zone D'G.

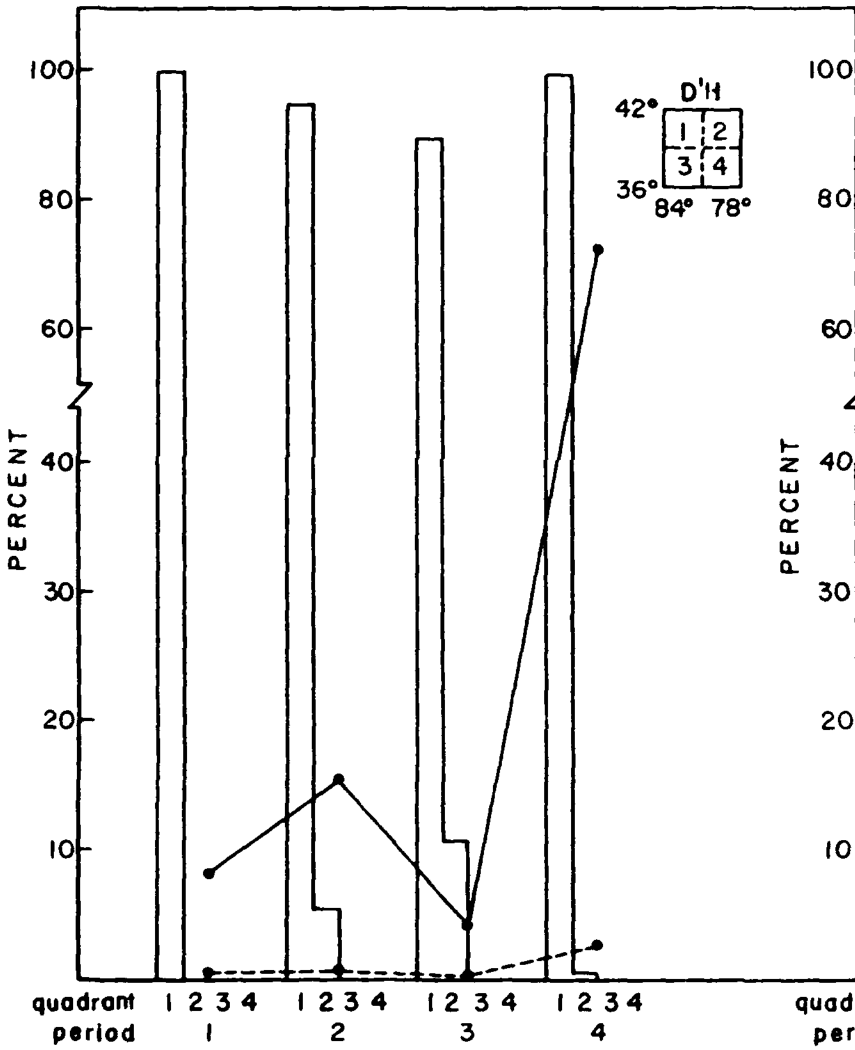


Figure 7. Zone D'H.

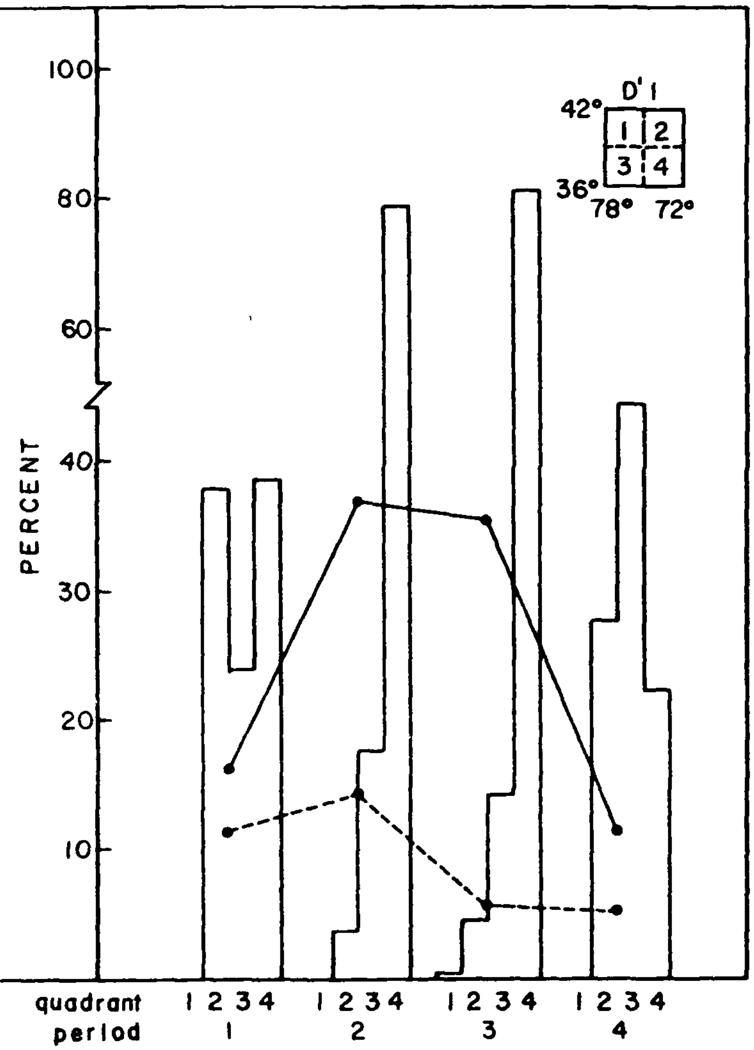


Figure 7. Zone D'I.

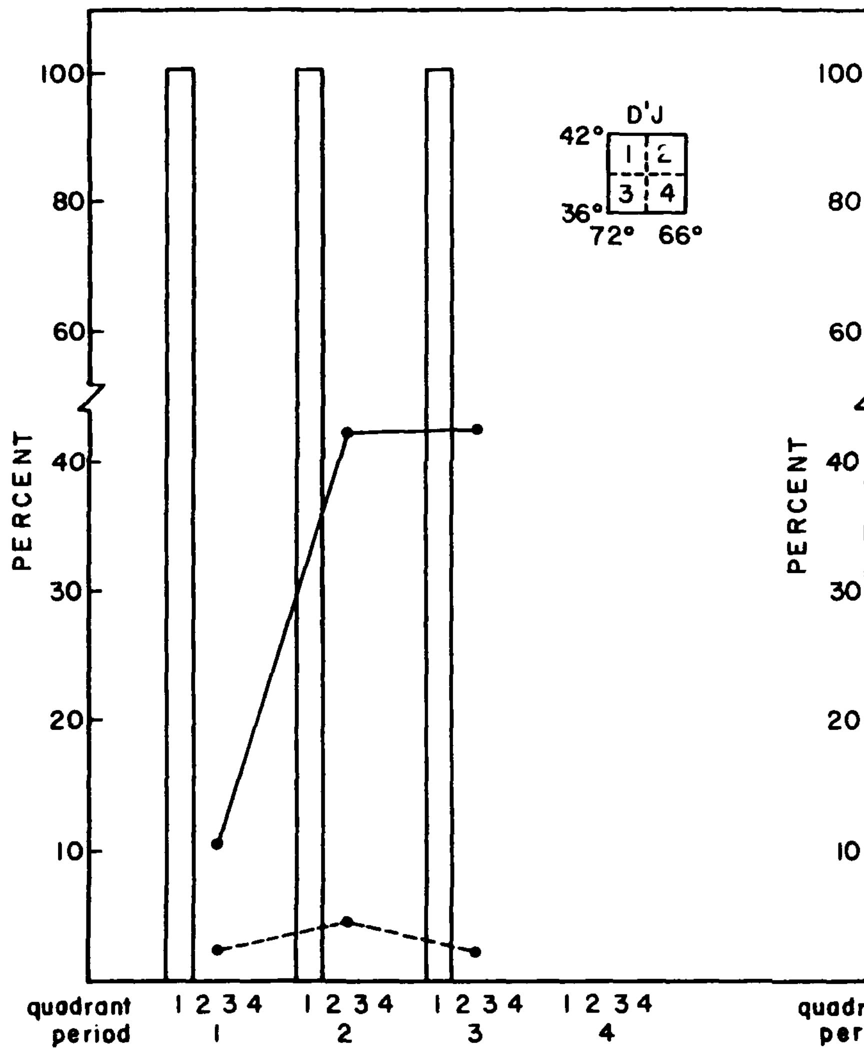


Figure 7. Zone D'J.

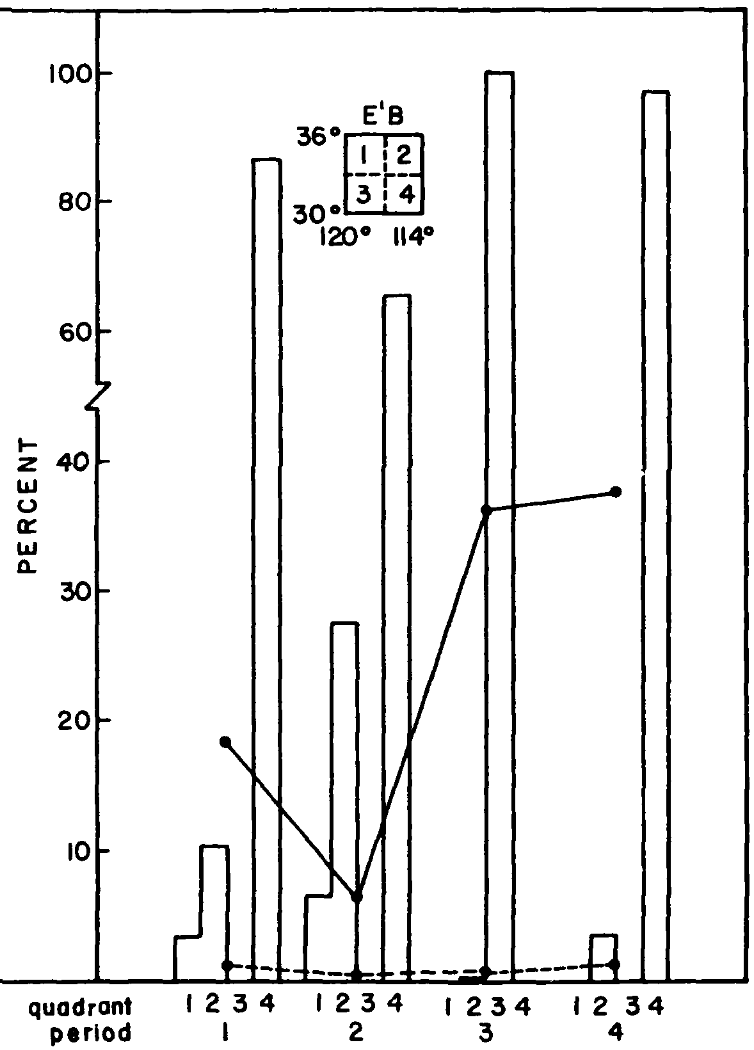


Figure 7. Zone E'B.

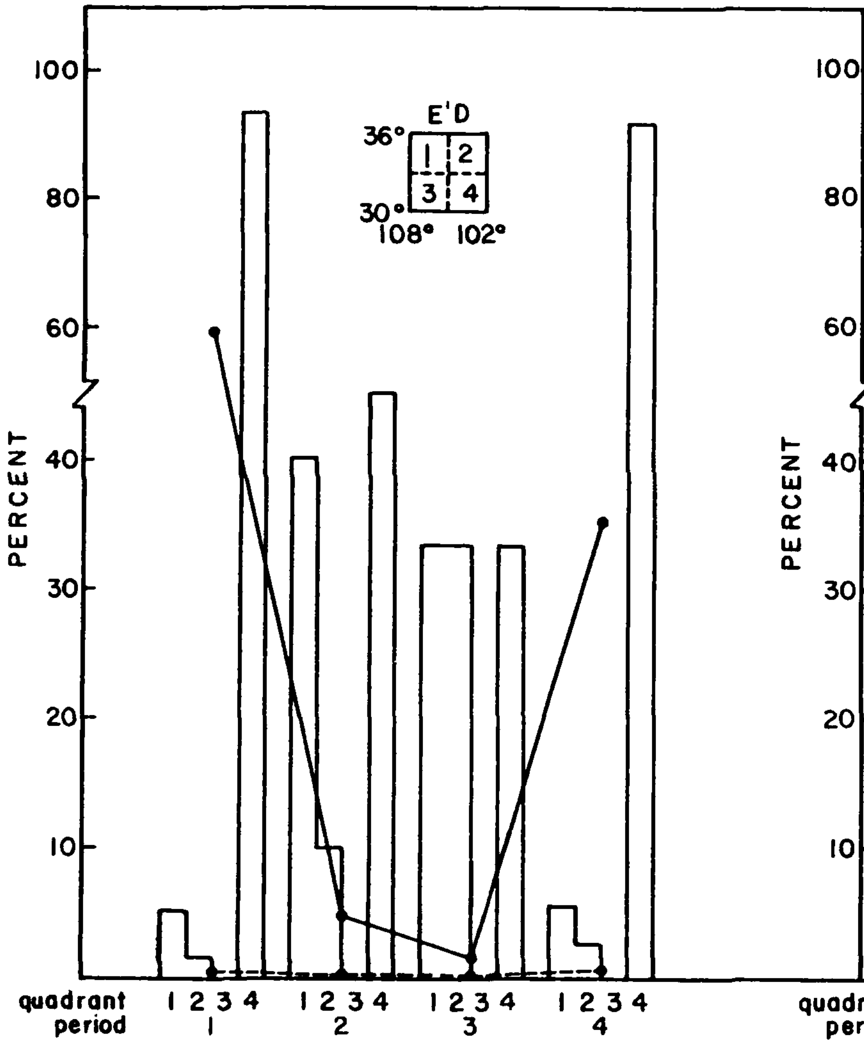


Figure 7. Zone E'D.

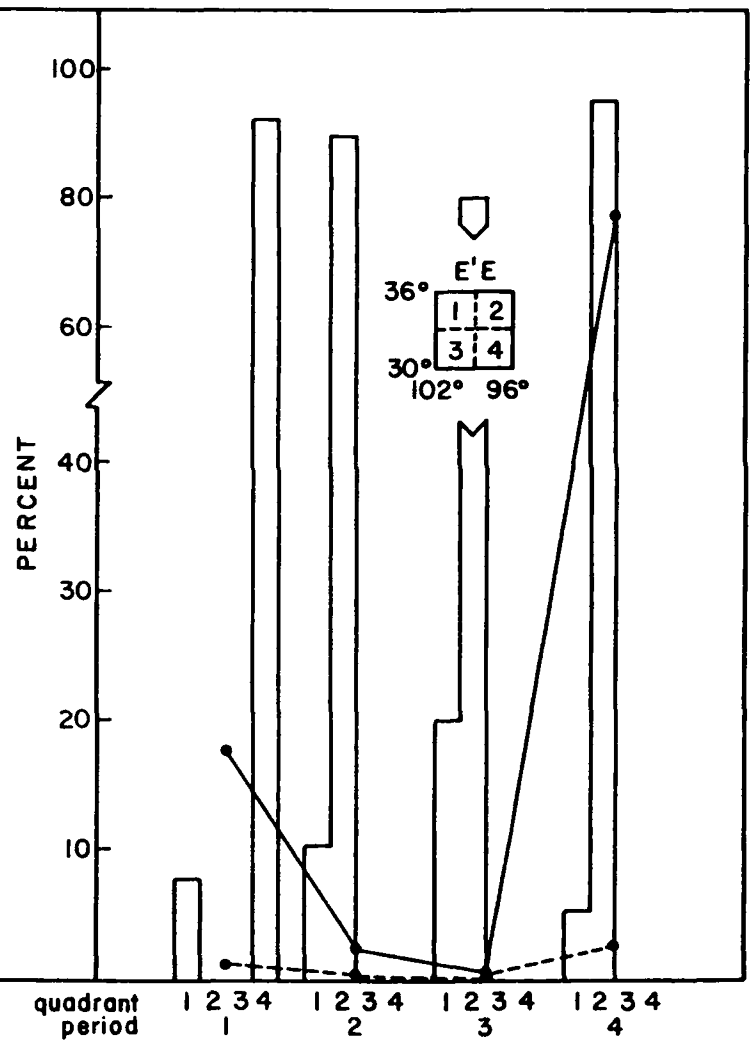


Figure 7. Zone E'E.

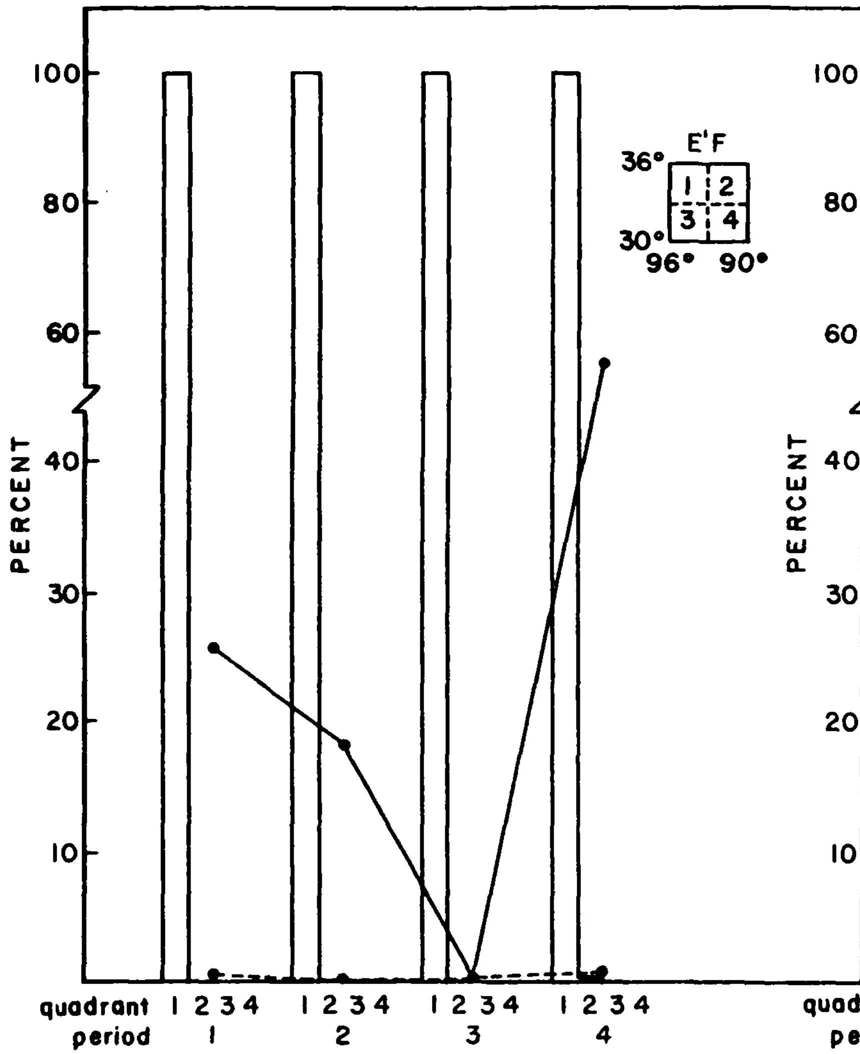


Figure 7. Zone E'F.

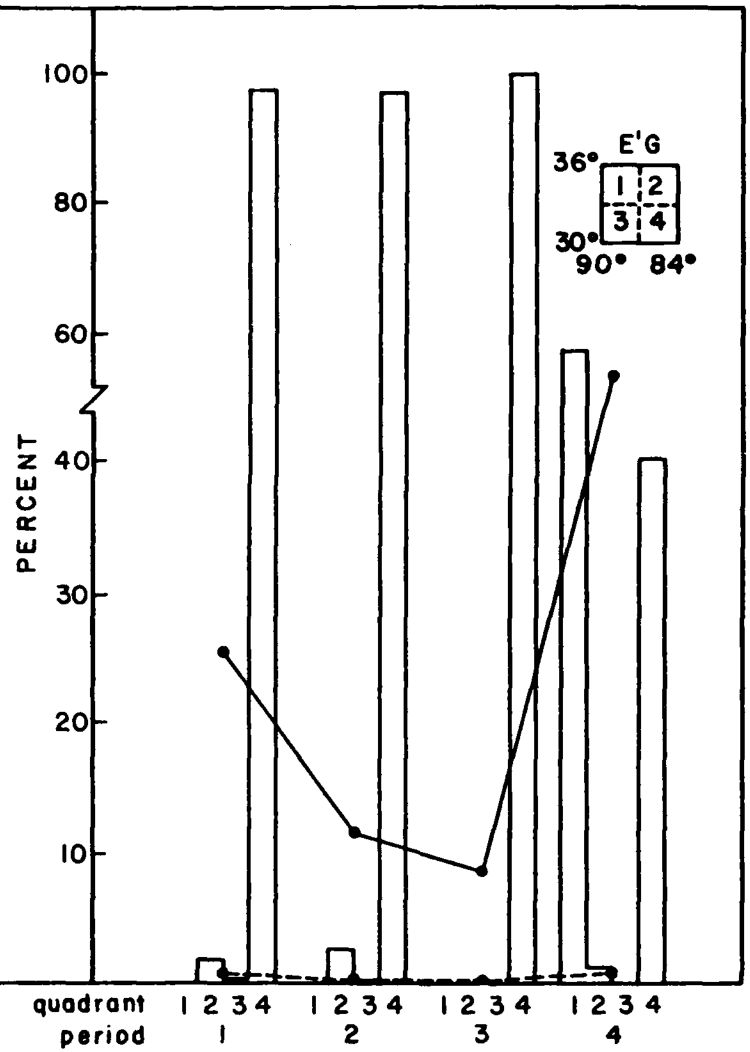


Figure 7. Zone E'G.

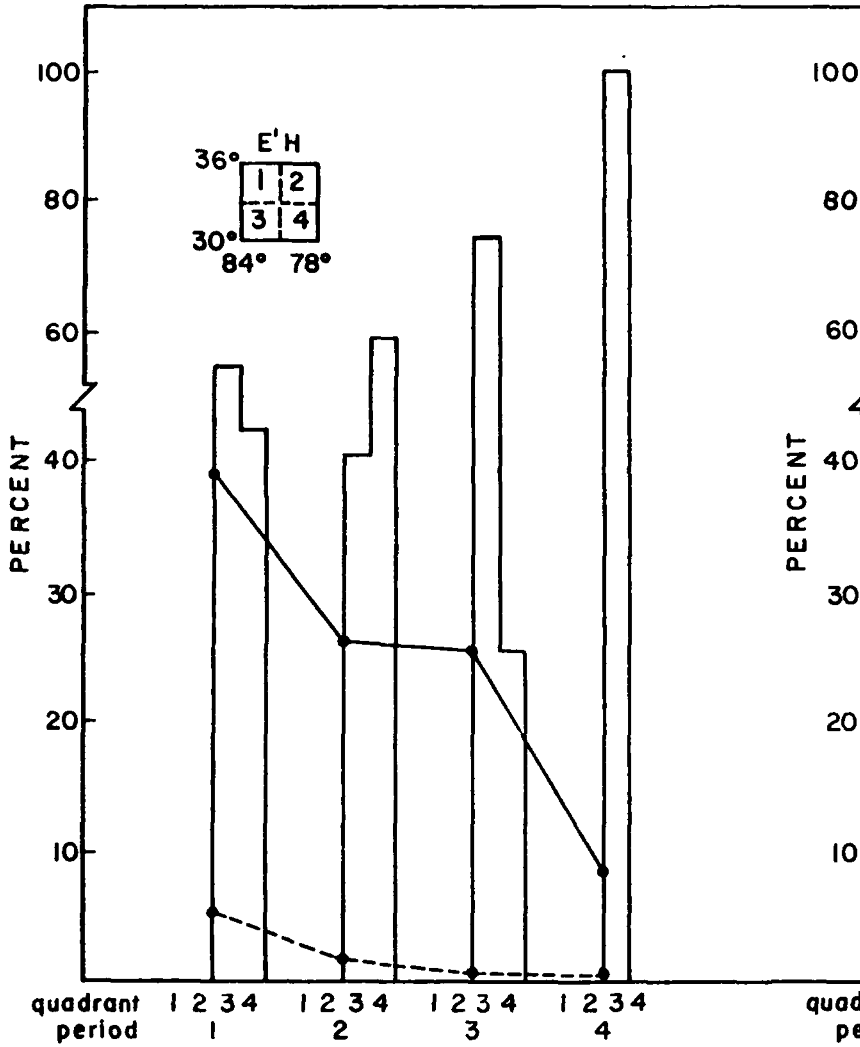


Figure 7. Zone E'H.

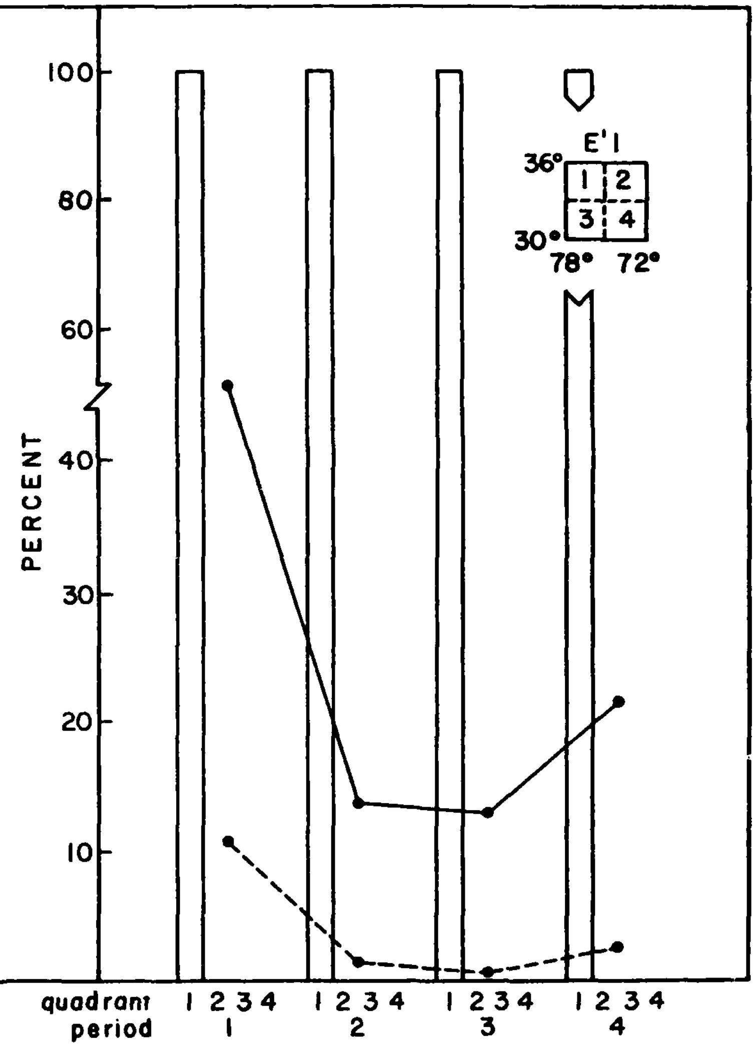


Figure 7. Zone E'I.

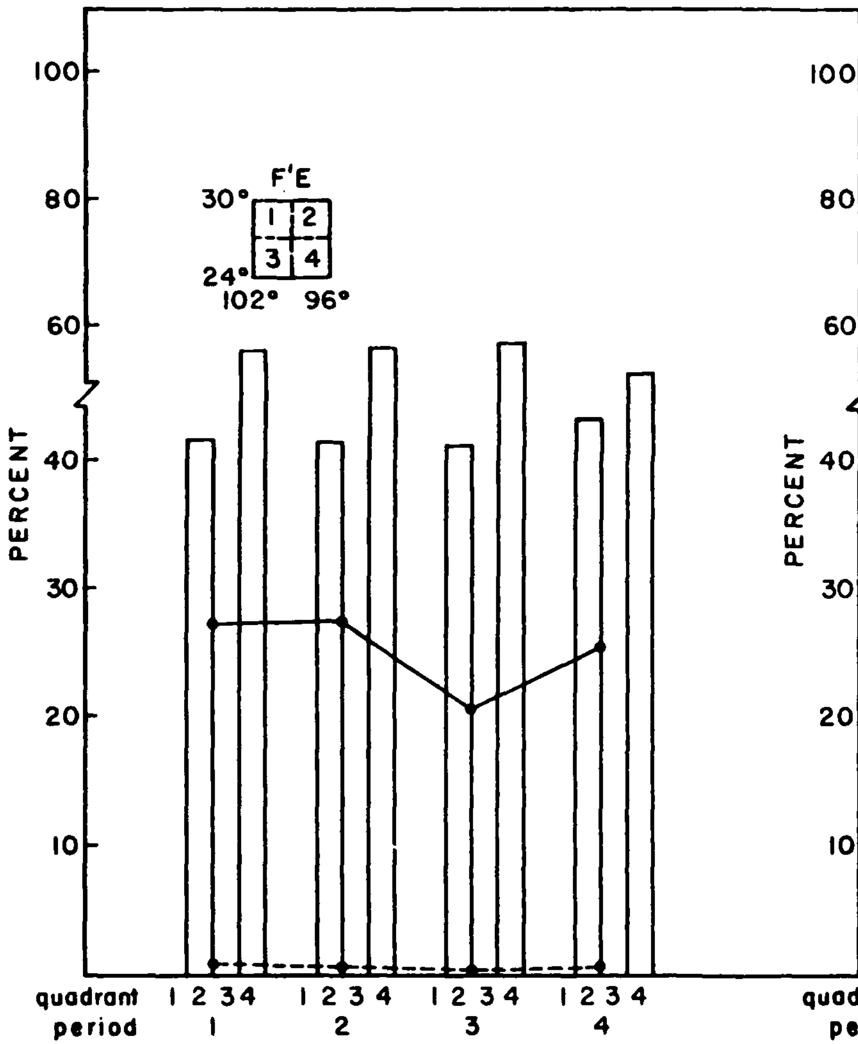


Figure 7. Zone F'E.

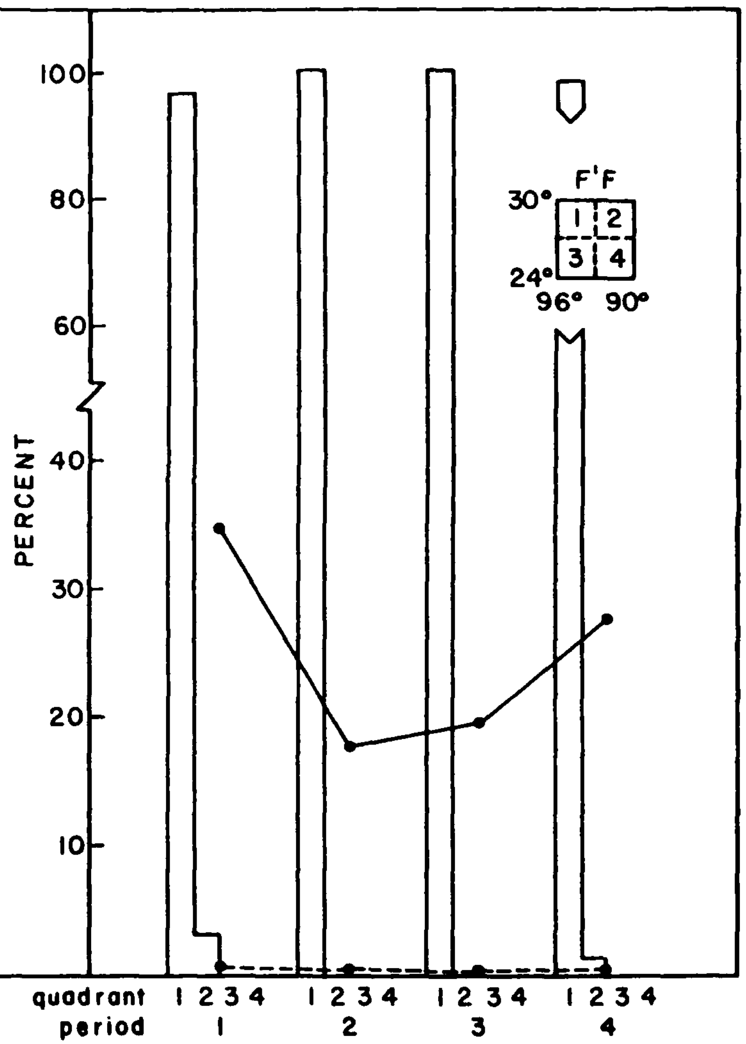


Figure 7. Zone F'F.

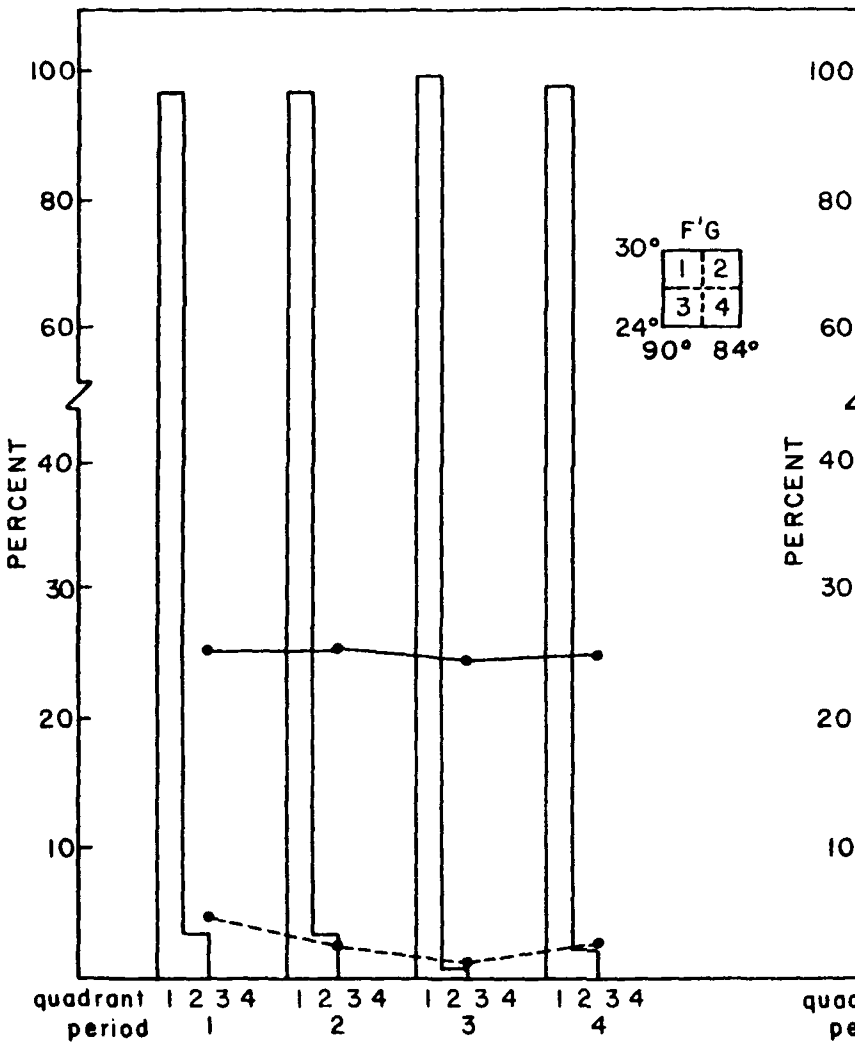


Figure 7. Zone F'G.

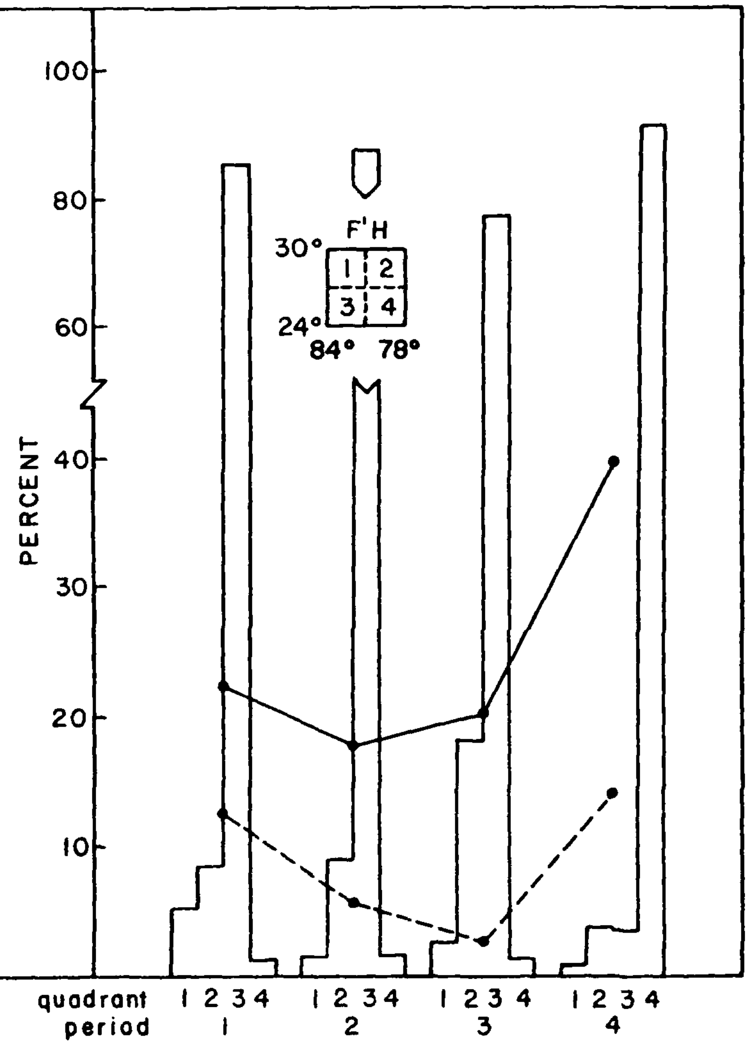


Figure 7. Zone F'H.

Figure 8A & B. Christmas Bird Count data for the combined years of 1972 through 1977 (December and January).

DECEMBER 1972-1976 CHRISTMAS COUNT DATA

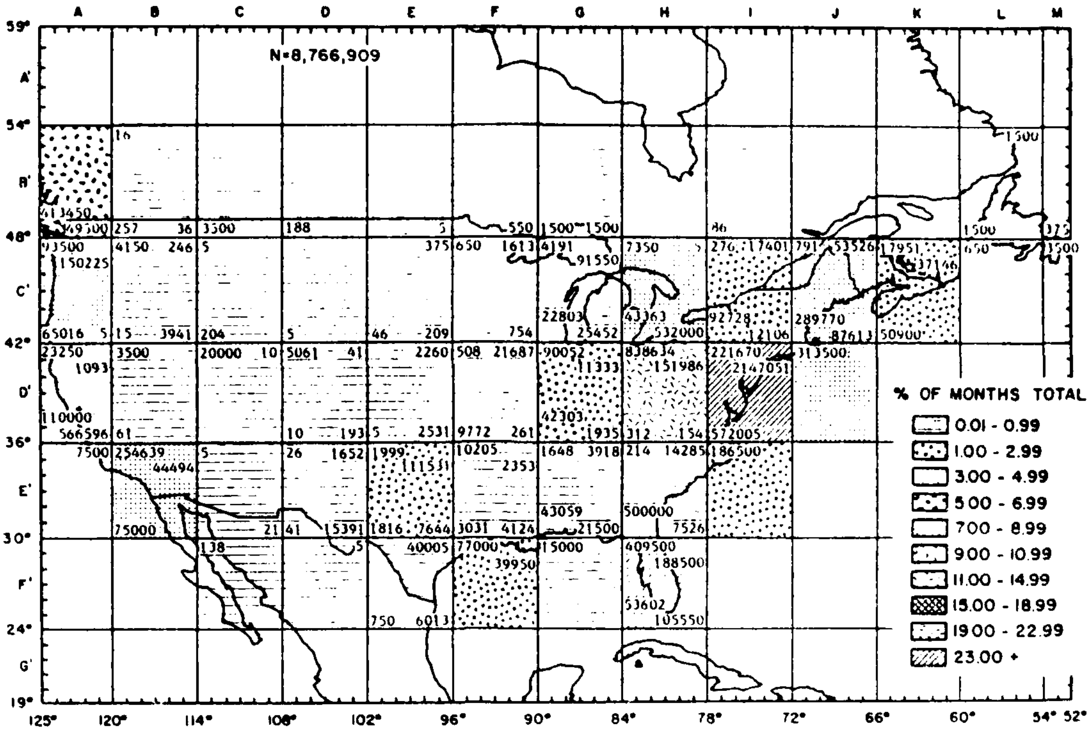
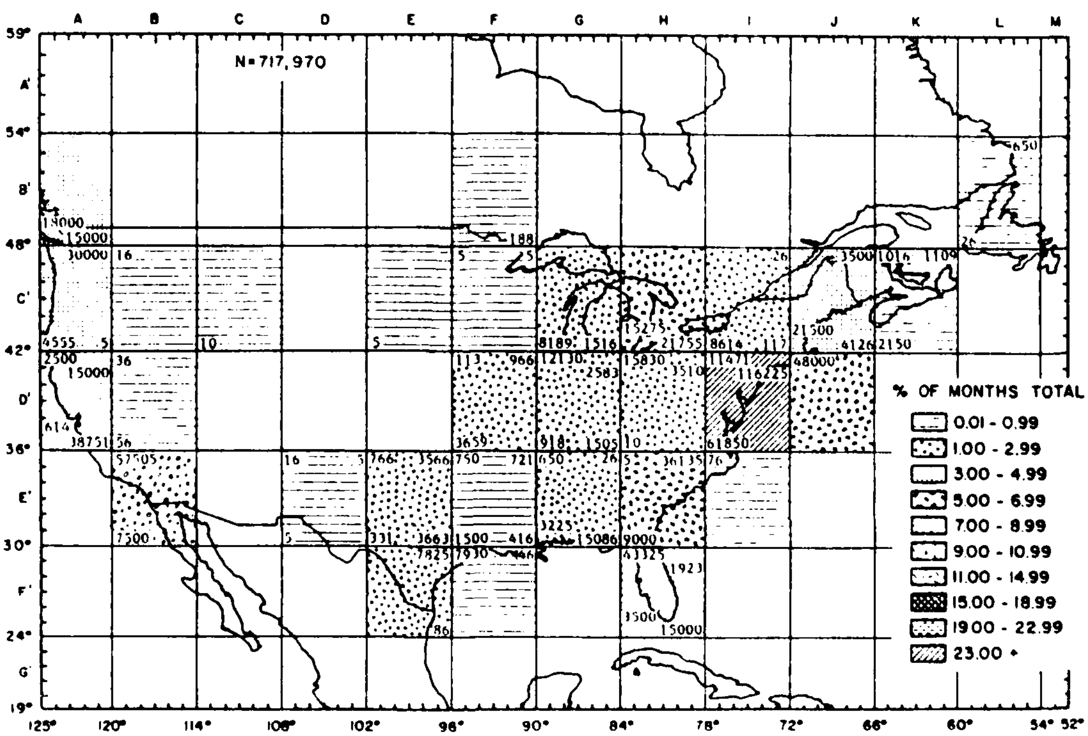


Figure 8A.

Figure 8B.

JANUARY 1972-1977 CHRISTMAS COUNT DATA



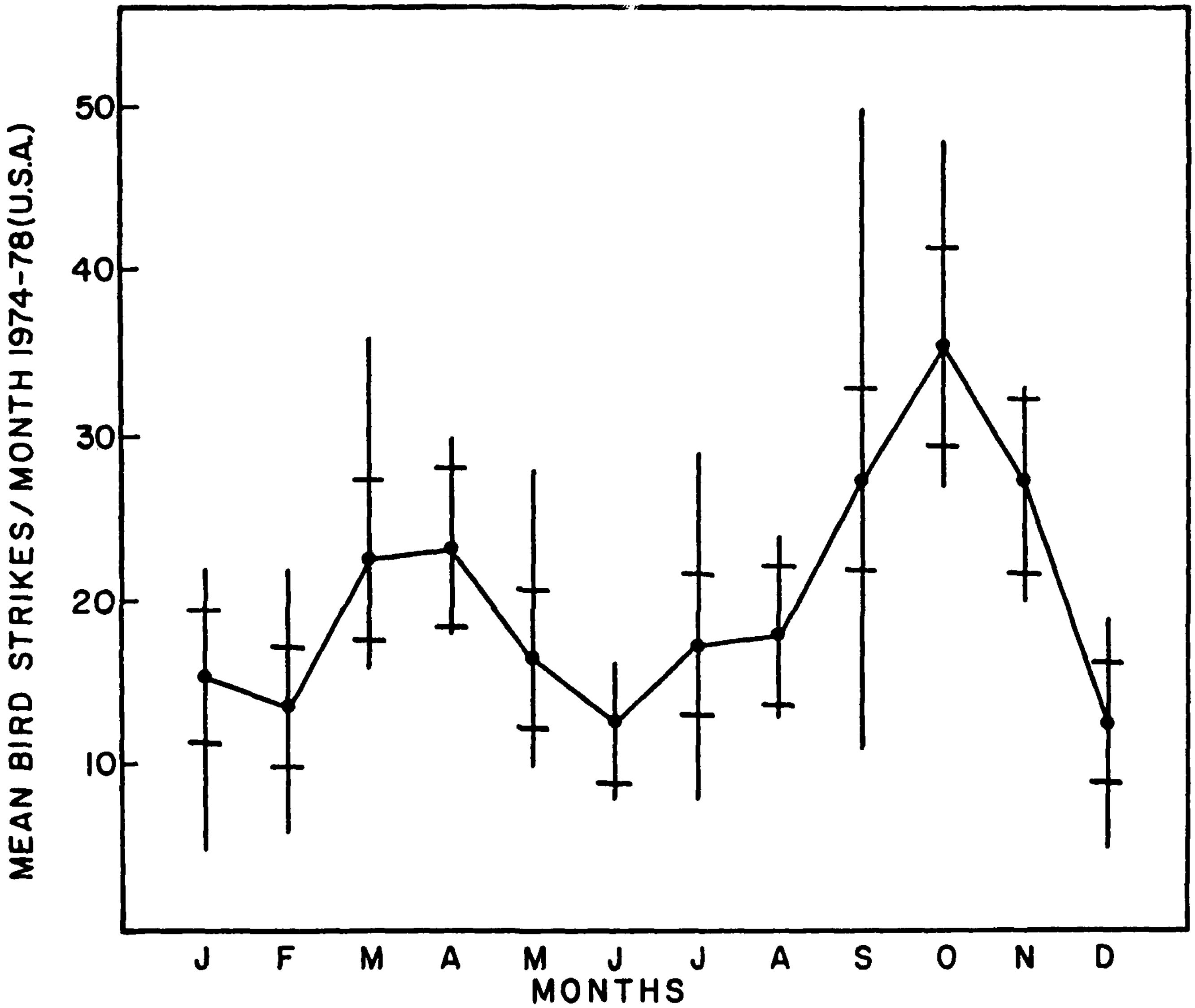


Figure 9. Mean number of USAF bird strikes reported per month. The solid line across the horizontal axis connects the mean values for each month. The vertical bars indicate the range between the high and low number of strikes reported during any one month. The short lines across the vertical bars denote the standard deviation about the mean.

Figure 10A - L. Percent of each month's total USAF bird strikes per 6^{o}-square Zone. Note that Blocks A and M are less than 6^{o}-square as a result of the map being trimmed to emphasize the lower 48 states.

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DEVELOPMENT OF COMPUTER-GENERATED PHENOGRAMS TO FORECAST REGION--ETC(U)
DEC 79 W E SOUTHERN AFOSR-77-3431
UNCLASSIFIED AFOSR-TR-80-0175 NL

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Figure 10A.

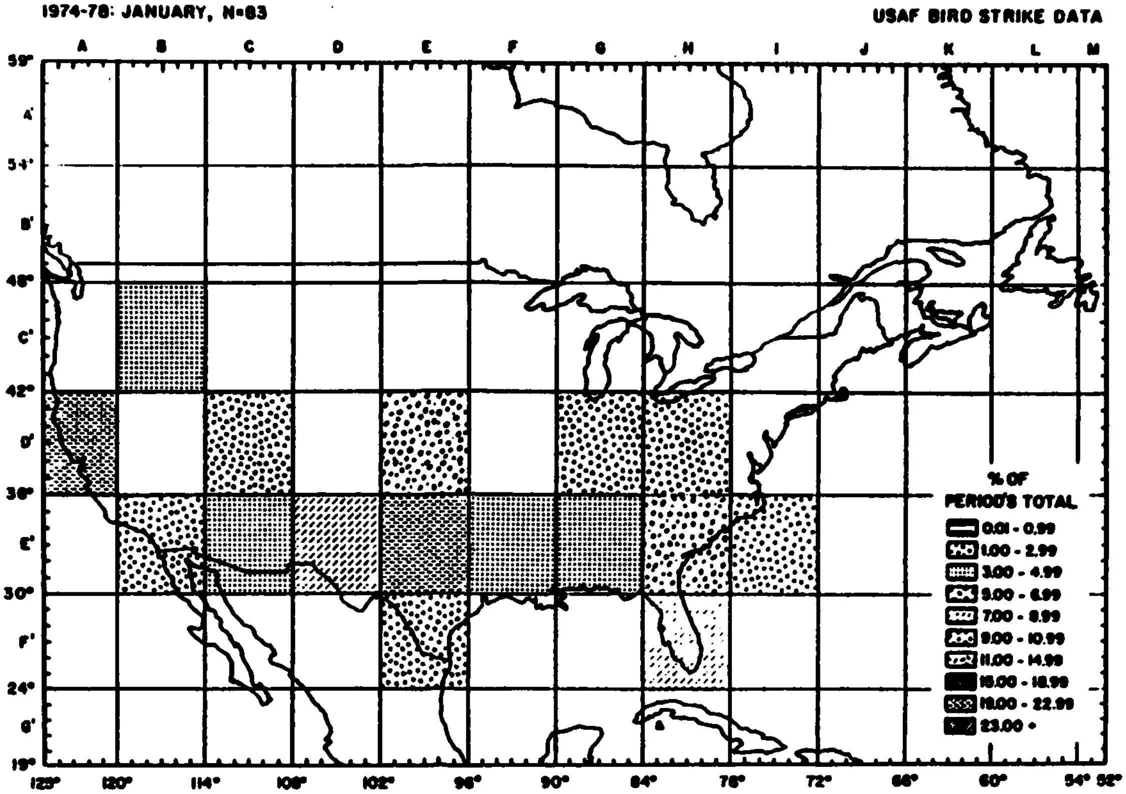

Figure 10B.

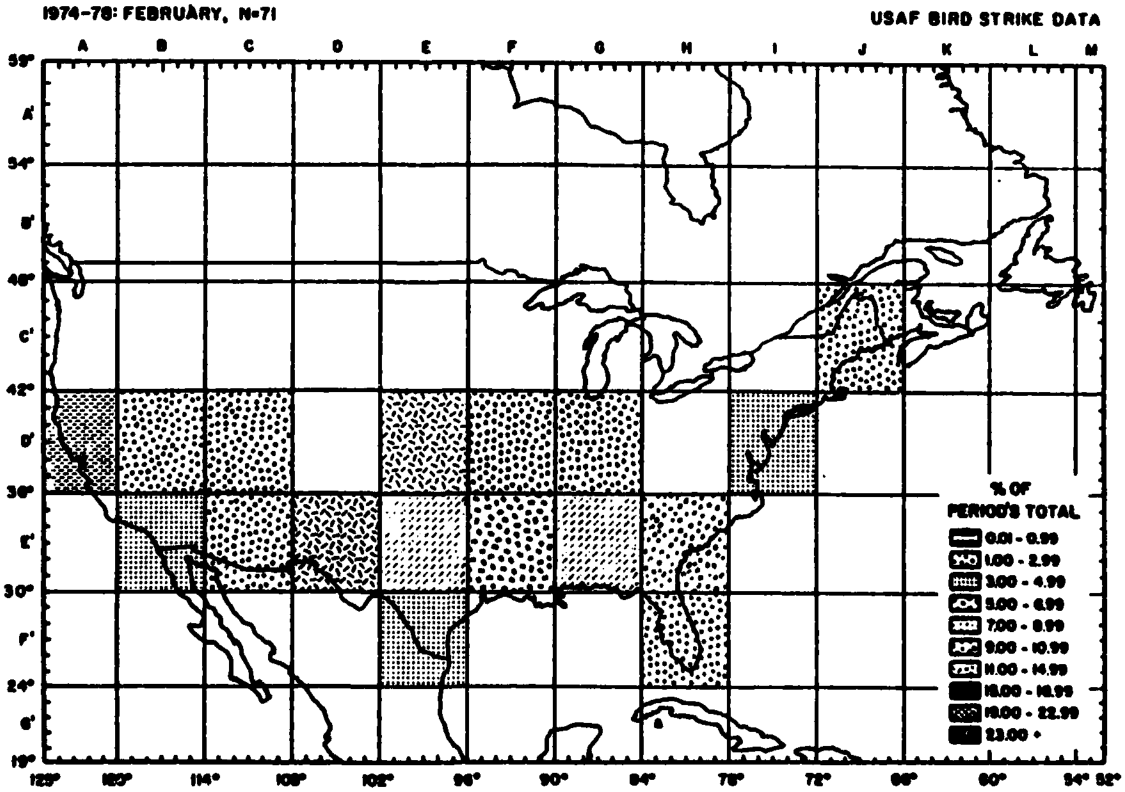

Figure 10C.

1974-78: MARCH, N=119 USAF BIRD STRIKE DATA

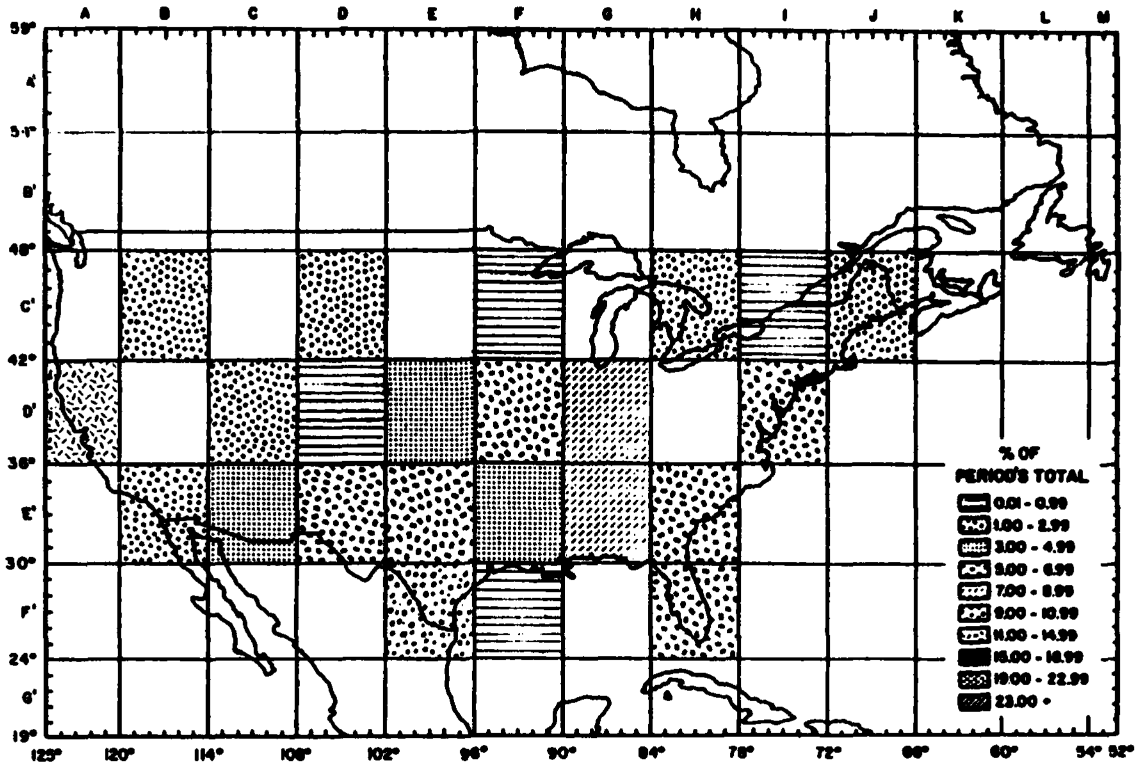

Figure 10D.

1974-78: APRIL, N=123 USAF BIRD STRIKE DATA

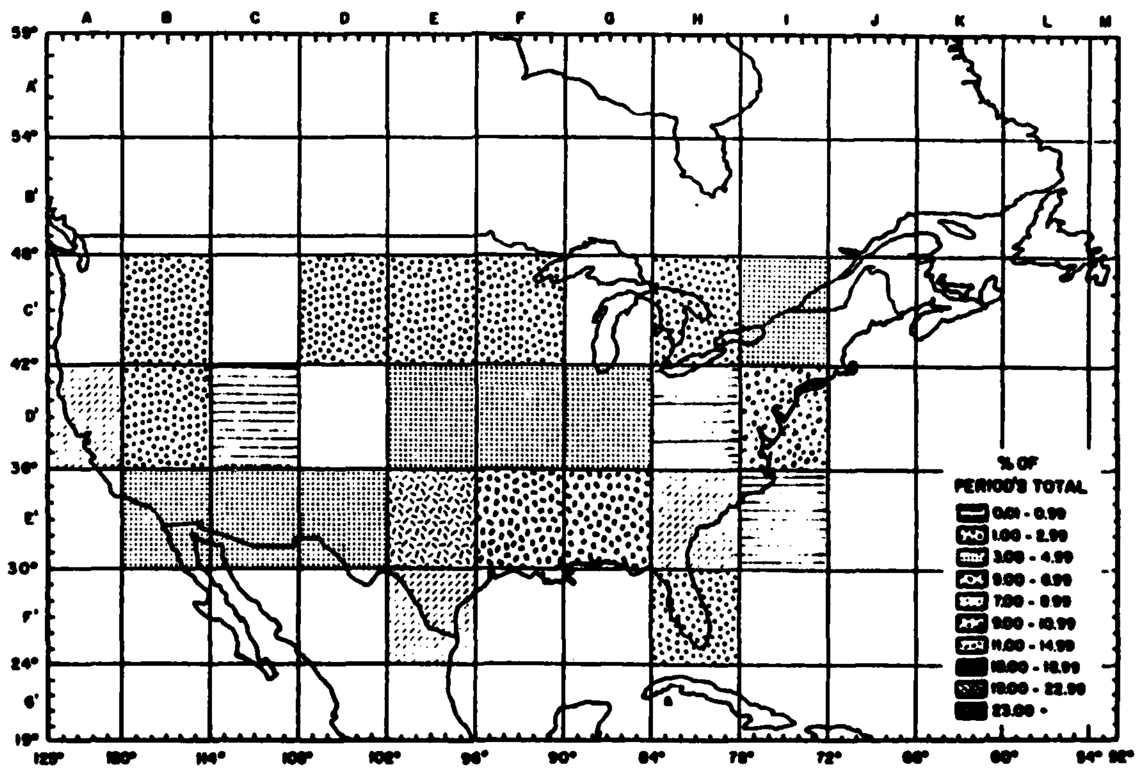

Figure 10E.

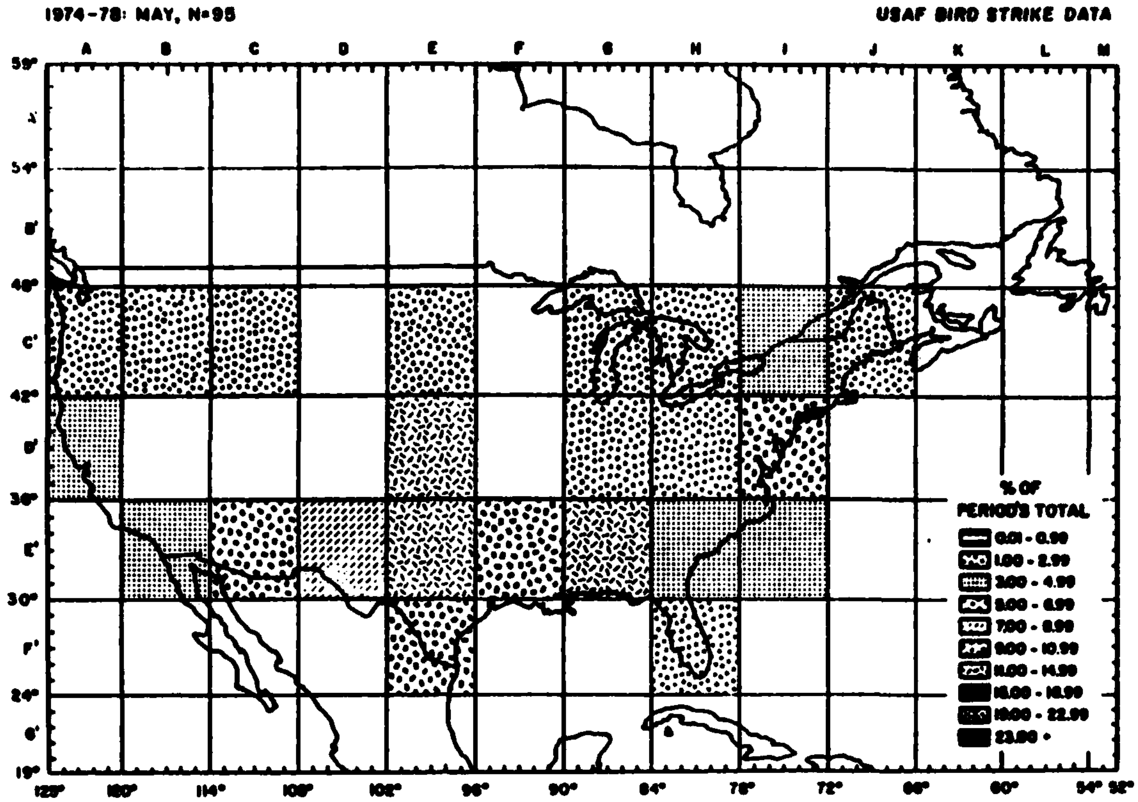

Figure 10F.

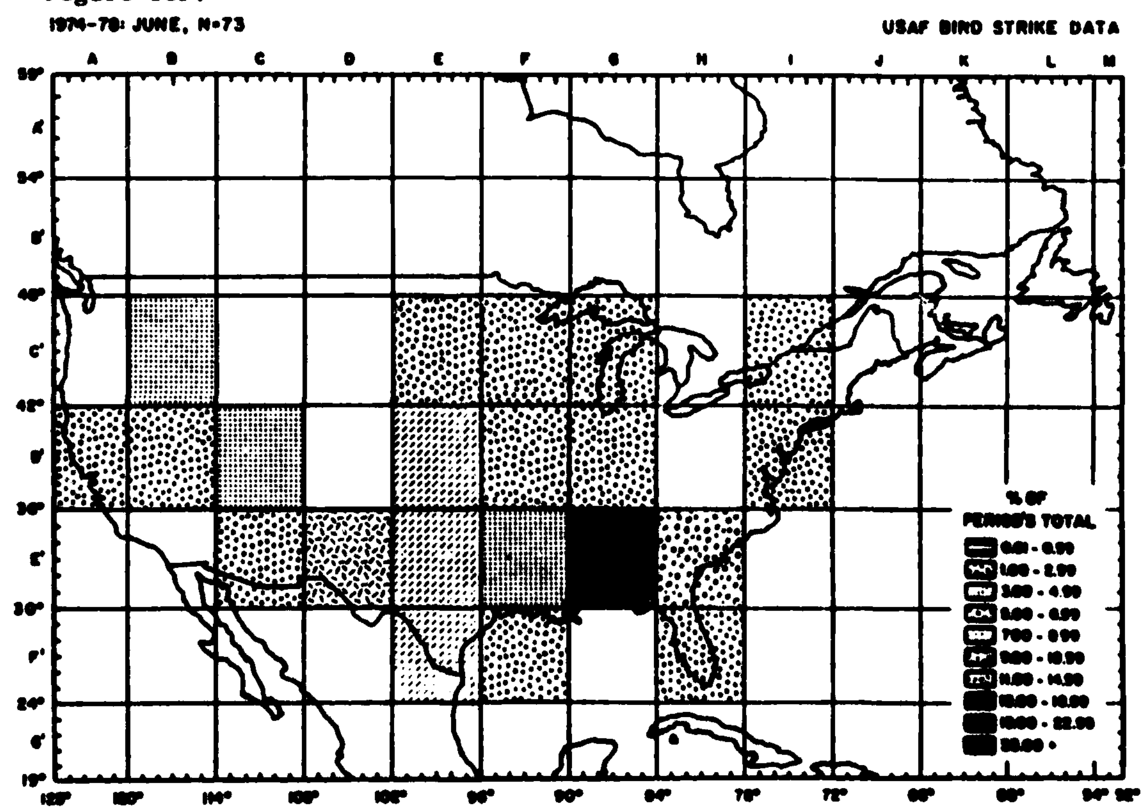

Figure 10G.

1974-78: JULY, N=90

USAF BIRD STRIKE DATA

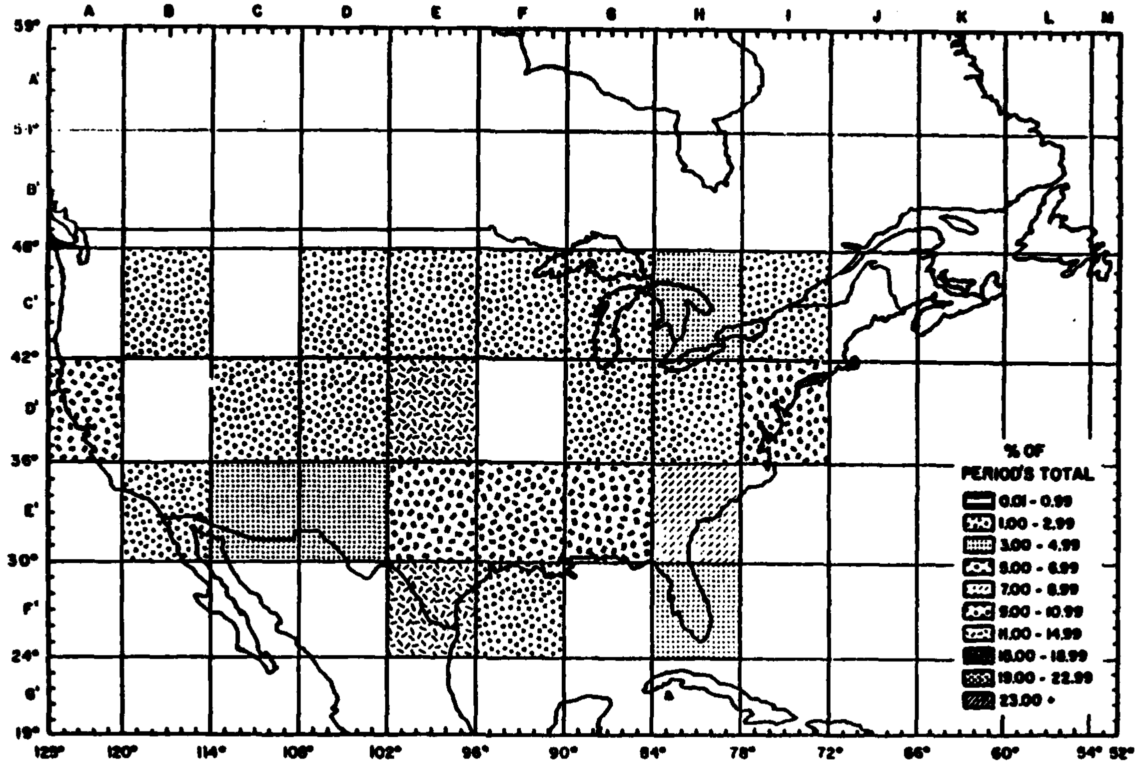

Figure 10H.

1974-78: AUGUST, N=99

USAF BIRD STRIKE DATA

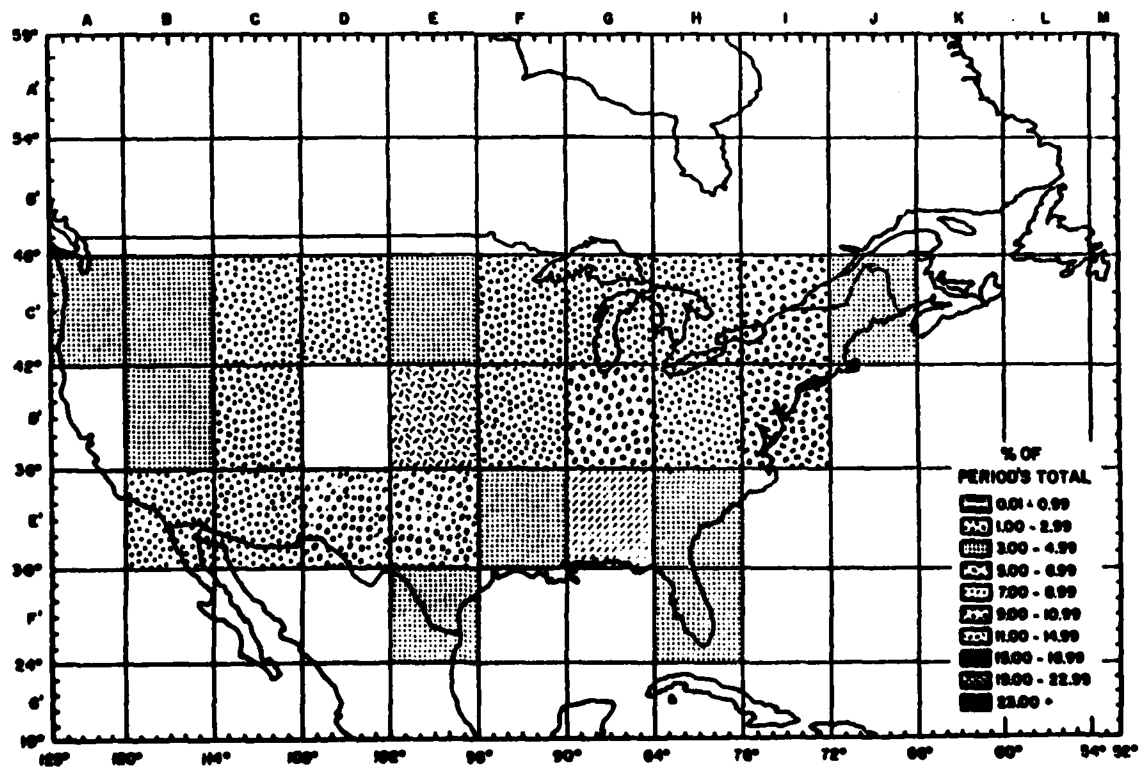

Figure 10I.

1974-78: SEPTEMBER, N=148

USAF BIRD STRIKE DATA

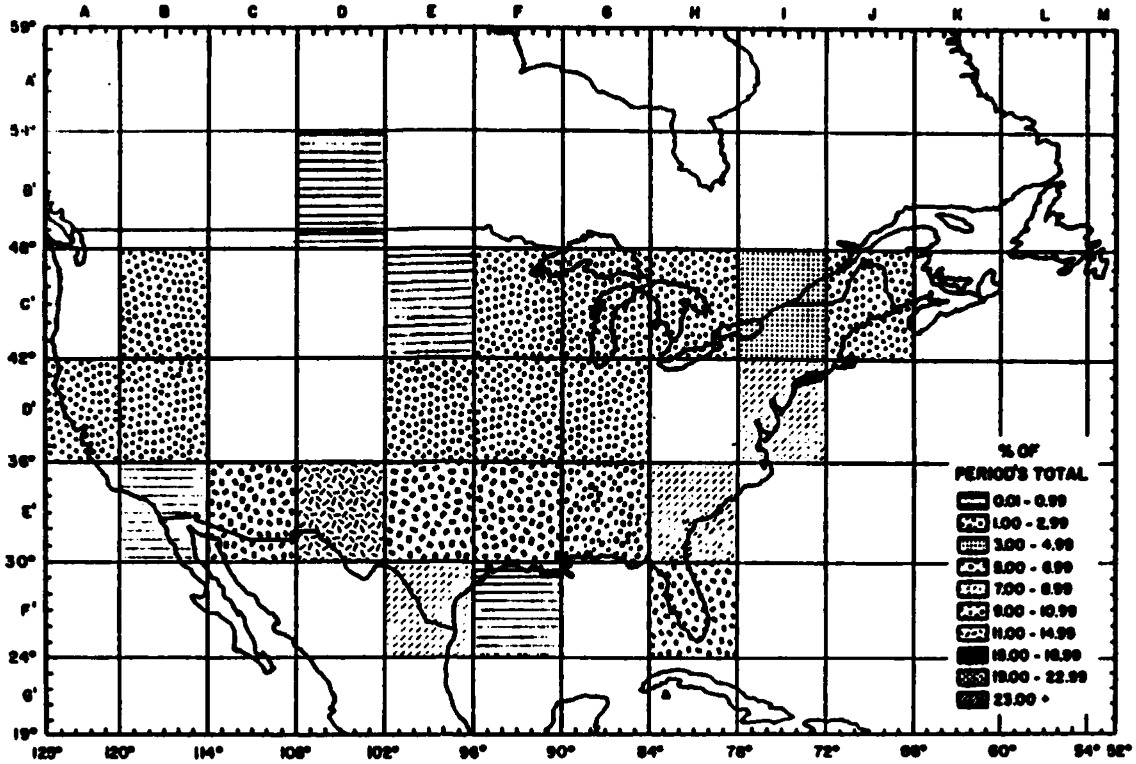

Figure 10J.

1974-78: OCTOBER, N=198

USAF BIRD STRIKE DATA

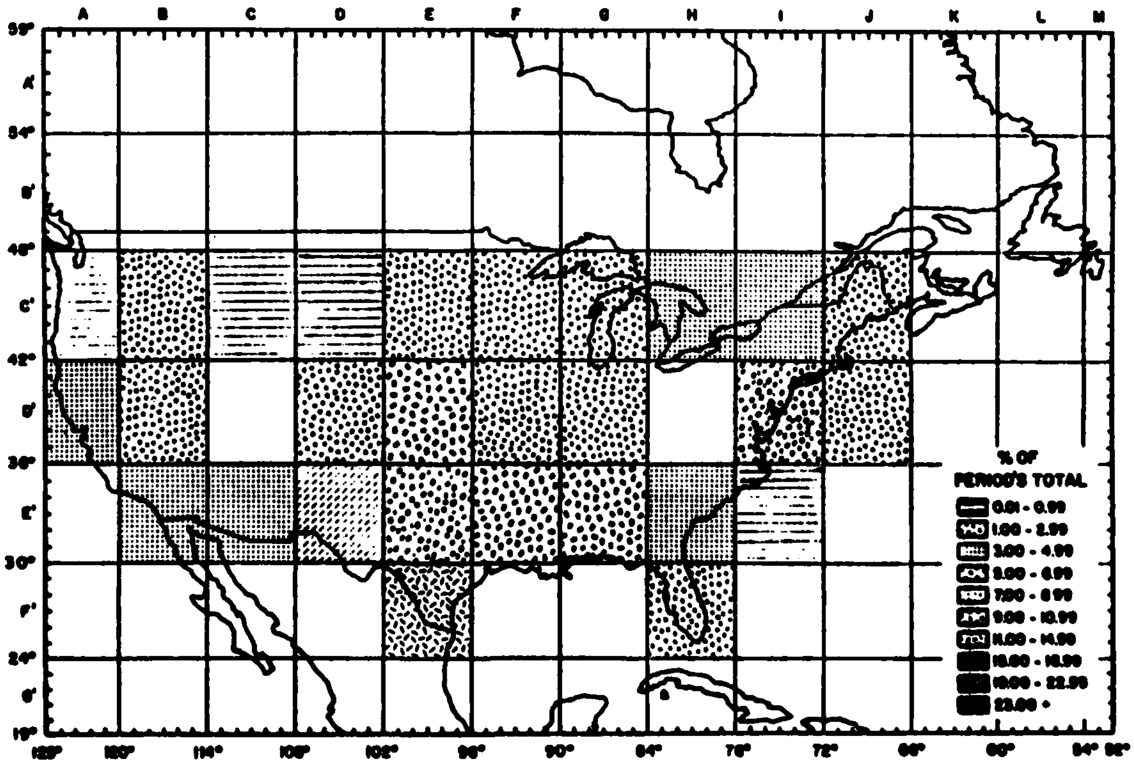

Figure 10K.

1974-78: NOVEMBER, N=160 USAF BIRD STRIKE DATA

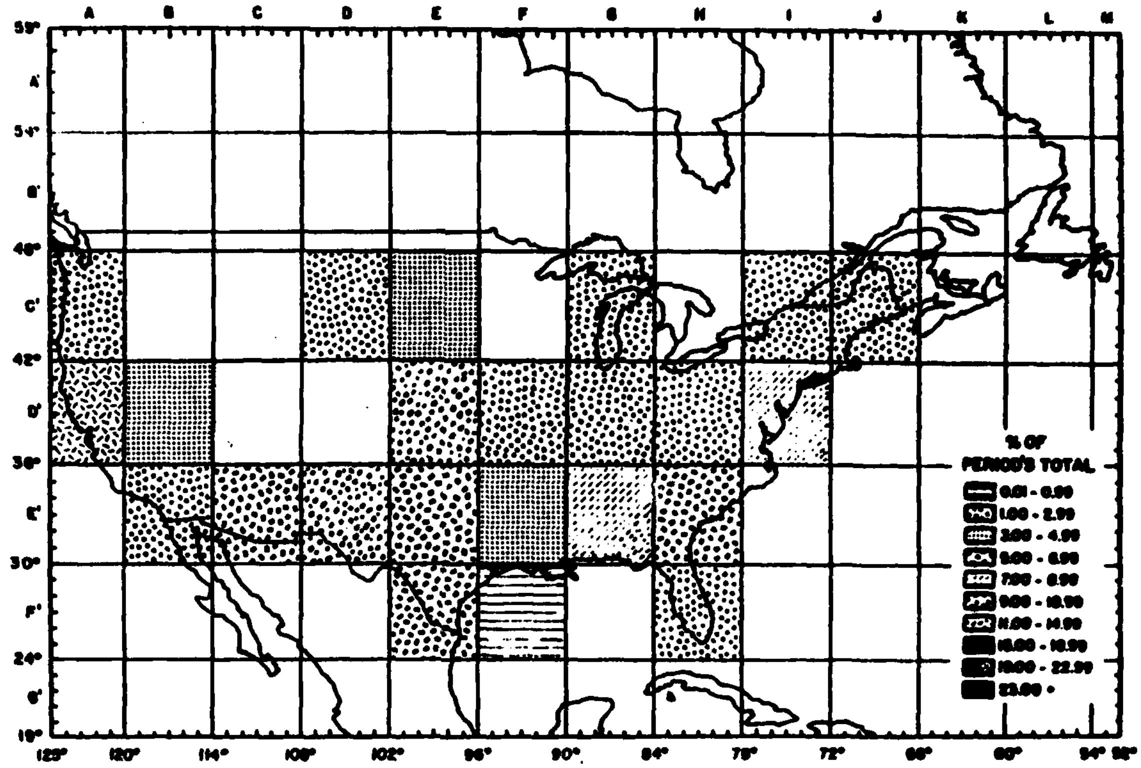

Figure 10L.

1974-78: DECEMBER, N=73 USAF BIRD STRIKE DATA